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FOR THE

PROMOTION OF THE MECHANIC ARTS.

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EDITORIAL.

ITEMS AND NOVELTIES.

The Channel Ferry.—The scheme to establish a line of steamers, upon a grand scale, to convey passengers and freight across the channel between Dover and Calais, which was first proposed by Mr. John Fowler, about seven years ago, is again attracting serious public attention and awaking much discussion, *pro* and *con*, from the journals of the countries more directly interested.

The great advantages to be derived from some method of transit which shall meet the requirements of present commerce and insure increased facilities and comfort for passengers, has received practical recognition in the actions of the two governments concerned, both of which have passed bills favorable to the establishment of some superior practical plan of international communication.

We learn from a contemporary* that, at a recent meeting, held at Dover, to consider the plan above named, the representative of its projector made the following statements concerning it: First, that the engineers had determined to have no halfway measures, but to carry out a plan which would not require to be enlarged and altered,

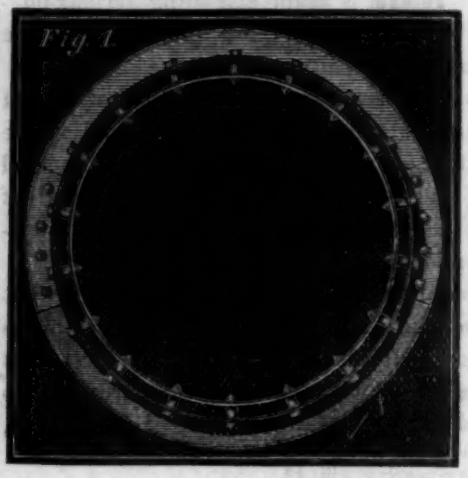
* Engineering, xiii, 43.

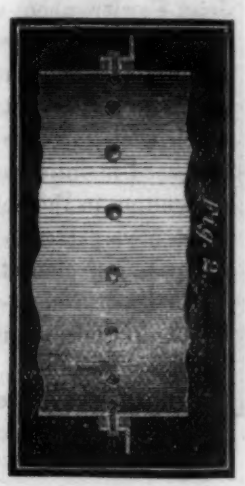
at loss of time, at additional expense, and at the cost of hampering and hindering the development of the great traffic anticipated; secondly, it was desirable, in their opinion, for the commercial success of the enterprise, that provision should be made for carrying the trains across the channel upon the steamers, so as to afford passengers an unbroken through train communication to Paris, and also that the same accommodation might be provided for goods.

Hooping Boiler Flues.—The recent report of the Engineer of the Manchester Steam Users' Association upon the application of encircling hoops to the furnace tubes and flues of boilers originally constructed without them, contains much information of a useful character. Want of space forbids the reproduction of more than a brief summary of this valuable document, to which, as well as to the pages of the leading English technical periodicals, we would refer those of our readers who desire to peruse the original.

"It is frequently found to be desirable to add encircling hoops to the furnace tubes of boilers already in use, either to admit of their working pressure being increased, or to render them safe at the one to which they may have been hitherto subjected." As these hoops, if not properly attached, give rise to serious trouble, the following report and illustrations were deemed serviceable:

"Fig. 1 gives a cross section of a furnace tube with encircling hoop, while fig. 2 gives a horizontal section, and fig. 3 an external plan view.

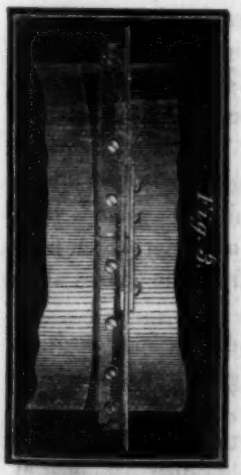


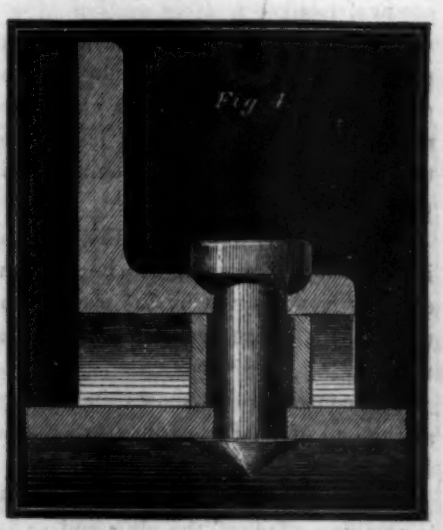


"The hoops should be of angle iron section, about 3 in. x $\frac{1}{2}$ in. They should be made in halves, so that they may be passed in at the manhole, and then riveted to the furnace or flue tubes in position, thus rendering it unnecessary to remove the tubes or to cut any opening in the boiler. The angle iron should not be brought into direct contact with the plates of the tubes, but a clear space of not less than an inch should be left between the two, the hoop for this purpose having a diameter some two inches larger than the furnace tube.

"The hoop should be secured to the furnace tube by rivets, spaced about six inches apart, blocking pieces through which the rivets should pass being inserted between the tube and angle iron, so as to give a solid abutment to the riveting, while the halves of the hoops should be connected together by butt strips riveted to their ends at the back. Sometimes these blocking pieces are made by cutting off a piece of bar iron, and punching a hole through it for the rivet. This plan is objectionable, as it forms too great a lump of metal around the rivet, and promotes the overheating of the plate. The blocking pieces should be made of a strip of iron not more than $\frac{3}{16}$ in. thick, bent round into a circular shape, the ends being welded together so as to form a short tube or ferrule."

A view of this mode of construction is given in fig. 4.





The object to be accomplished by the water space between the angle iron ring and the tube is to allow of perfect circulation of water be-

tween them, and thus to avoid the objection connected with the plan of attaching the rings directly upon the tube, in which the plate easily cracks at the rivet holes from the overheating of the tube.

"In fixing hoops in pairs, one hoop should be set a little out of line with the other, so that the flanges may not be in contact, or close enough to form a harbor for incrustation."

It is also "recommended that in every boiler of ordinary dimensions, one set of hoops should be applied to the tubes at about 5 feet from front end."

Shaw's Compound Propeller Pump.—In the illustrated description of this machine in our last issue, reference was made to the ingenious contrivance of a hydrostatic disc or water bearing, upon which is sustained the weight of gearing, shaft and water, and the downward reaction of the lifting power, thus effecting a great saving in power, and permitting of the economical use of pumps of great length. A good estimate of the amount of pressure exerted upon the bearing may be formed from the statement that a pump of this form, 20 inches in diameter and raising water to a height of 50 feet, with propeller blades and shaft weighing, say 1 ton, the total pressure to be sustained by the bearing is 4½ tons, or about 10,000 pounds, in which there is no estimate for the downward reaction of the surplus power needed to forcibly eject the elevated liquid. It is clear that with a bearing of ordinary construction the effect of this enormous pressure would be a great loss of power from friction, rendering pumps of considerable length altogether impracticable from an economical standpoint, even could materials be found of sufficient strength to resist so great a strain, combined with a velocity of 200 rotations per minute.

These serious objections the inventor has ingeniously met by the introduction of a water bearing, or device by which the shaft is lifted entirely from its rest by the pressure of a body of water which floats upon it, the entire pressure arising in any case from the causes above named.

This contrivance is shown, in external view and in proper position, at the end of shaft just beneath the pulley in fig. 1, and, in section, in fig. 2.

It consists of an outer stationary disk, supported from pillars resting on upper face of the pipe, and an inner movable disk, attached to, and rotating with the shaft. The hydrostatic pressure is applied by the force pump, indicated in fig. 1 by a pipe entering the lower face

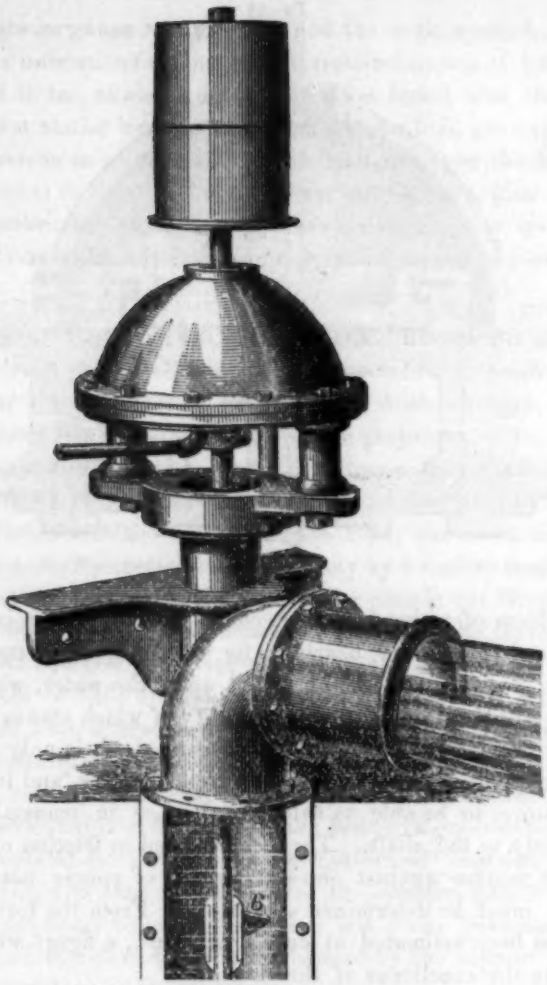


Fig. 1.

of outer disk; and, being operated by the engine driving the pump, forces a quantity of water between the faces of the disks. The result is the lifting of the inner disk (and with it the shaft) from contact with the outer one.

The water having performed its work is permitted to escape about the circumference of the disk, the escape being regulated by the device of an elevated edge in the outer, and a corresponding groove in the inner disk.

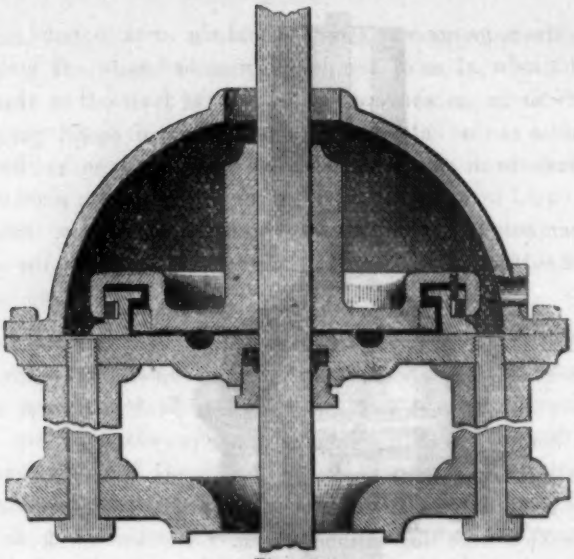


Fig. 2.

The problem of estimating the economy of the pump is rendered much easier by the water bearing; for seeing that, as much of the friction and pressure must be exercised upon the water, which would return it in the form of heat—the quantity of which stands in a well-known ratio to the amount of power consumed—it is only necessary to know the quantity of water escaping from the disk, and its increase in temperature, to be able to calculate the loss in transmitting the power directly to the shaft. The loss involved in friction of the elevated water column against sides of pipe is of course not here involved, but must be determined separately. From the former cause the loss has been estimated at only 5 per cent., a figure which bears testimony to the excellence of the invention.

Pressure in Steam Boilers.—The question as to whether the pressure in a steam boiler was equal or different at top and bottom, concerning which there seems to be some difference of opinion amongst engineers—though it is difficult, from the simplicity of the facts involved in considering the question, to see how a difference of opinion should exist—has nevertheless been experimentally determined by the Messrs. Hunter, at their establishment in this city. An elbow was attached to the end of the blow-off pipe which entered the mud-drum; into this a plug was screwed, and tapped to receive a half-inch pipe;

to this a steam gauge was attached and the cock opened. On comparing the indications of the gauges attached at top of boiler and to the top of drum, as above described, it was found that the pressure was greatest at the bottom, by a pound and a half, proving, as might readily have been predicted, that the pressure upon the bottom of a boiler is equal to the steam pressure indicated above, plus the weight of a water column equal in height to the difference in level between drum and surface of water in boiler, and in diameter to that acting on the gauge.

The Saint Gothard Tunnel.—Scarce has the world ceased its wonderment at some great scientific achievement, or engineering triumph over the obstacles of nature, when fresh schemes, still more gigantic, born of preceding successes, are projected.

The great advantage to be derived by France from the completion of the Mont Cenis tunnel, bringing the cities of that country in intimate communication with the nations of the East, has awakened anew a project to unite Switzerland and Germany by a similar tunnel through the Alps at the pass of St. Gothard. The plan is not altogether new, for ever since the former tunnel was perfected the Governments of Switzerland and Germany, influenced by the fear that a vast commerce would be built up and diverted into France by its successful completion, have appreciated the importance of opening a new commercial highway on their side of the Alps. National jealousies have doubtless served to prevent the plan here named from assuming a definite form; but now that these have been to a great extent removed by the events of the past year, we are informed* that the project has been revived, and that a contract for the construction of the tunnel has been definitely concluded between the Swiss government and a syndicate of the German bankers, backed by the support of the Imperial government of Germany.

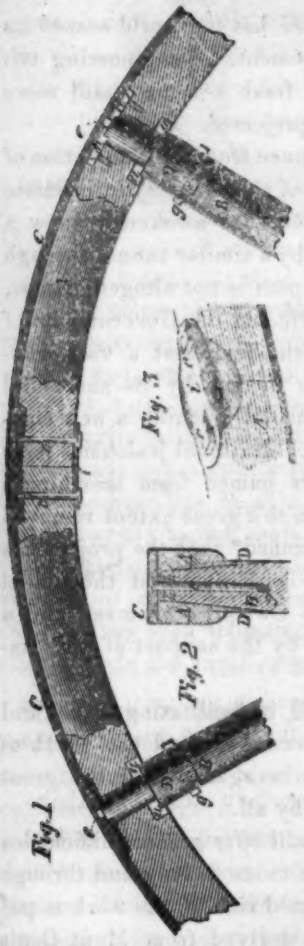
The importance of the projected tunnel in facilitating travel and influencing a vastly increased traffic between Asia and the north of Europe, cannot be overestimated, and the inauguration of the great enterprise will be looked for with interest by all.

The completion of the proposed tunnel will offer greater difficulties than that through Mont Cenis. It will be twice as long and through rocks more difficult to pierce. The estimated cost of the work is put at $37,000,000, and from the experience derived from Mont Cenis

* Iron World and Manufacturer.

and other similar works in various parts of the world, and the great improvements which have been made in tunnelling machinery, it is confidently anticipated that the enterprise will be brought to a successful termination in a proportionally much shorter time.

Improved Carriage Wheel.—The accompanying engravings illustrate an invention patented by J. T. Shelley, Esq., Pennsylvania, designed to secure the spokes more effectually in the fellies of wheels, and to attach the tire more securely to the wheel, at the same time preserving its strength.



By referring to the engraving, it will be observed that plates are welded upon the inner face of the tire, in such positions as to overlap the joints of the fellies. These plates, shown at *b*, are furnished with female screw threads to receive the ends of bolts, *c*, *c*, which firmly secure the fellies and tire at once, without requiring the drilling of the tire, and rendering it by so much the more durable. The spokes are attached to the wheel as follows. The ends of the spokes for fitting into the mortices of the fellies are tapered to admit of the attachment of an iron ferrule, *D*, which are made flush with the surface of spokes. There are wings, *a*, *a*, on either side of the ferrules to strengthen those portions of the spokes which enter the fellies.

A number of short grooves are made on the inner face of the tire, to correspond to the number of spokes, and each groove corresponds to a hole made in the axis of the spoke. Each of these passes down to a lateral oblong perforation in the ferrule *D*, and receives a pin, *e*, which, after having been properly wedged down, are firmly held by the key *g*, the ends of which are filed off even with the ferrule. To prevent lateral motion of tire or spoke, and the working loose of the pin, *e*, iron plates, *h*, are set into

the tire face of fellies across the ends of the spoke tenons secured by screws; which plates have perforations to correspond to the diameter of the bolts *e*.

Burnt Iron and Steel.—W. M. Williams has given the result of some inquiries into the causes of this phenomenon, to the Chemical Society of London. After some remarks upon the physical characteristics of the damaged materials, he asserts that he has found in all the samples of iron which he has subjected to examination, particles of black oxide more or less abundantly distributed throughout the mass. These are, however, absent in burnt steel. The method which he suggests of quickly deciding this question, is to take a small quantity of fresh borings or filings, and to cover them with some diluted nitric acid. As the iron dissolves, the free oxide separates and remains suspended in the liquid, rendering it dark in color. These particles shortly disappear, and are thus to be distinguished from separated carbon. No such discoloration takes place with good irons.

The cause of the burning of iron he explains as follows: As soon as the small quantity of carbon is removed from the heated mass by oxidation, this process extends to the iron itself—not only upon the surface, but into the interior. The higher the temperature, and the longer the exposure, the greater is the quantity of carbon necessary to protect the iron; and this, in the author's opinion, is the reason of the failure to produce merchantable iron by the Bessemer process. The high temperature and great exposure of the metal in the converter to the air, causes oxidation of the iron to take place even in the presence of considerable carbon. The best iron, therefore, should be that in which carbon is brought to the lowest possible proportion, without oxidation of the iron.

Burnt steel the author considers to be steel which has, by reheating, lost some of its carbon by oxidation, and by sudden solidification has had the resulting carbonic oxide imprisoned in the interior of its mass. The well known permeability of iron for certain gases renders such a process not difficult to understand.

The structure and properties of "burnt iron and steel," are therefore "caused by the presence of intermingled particles of combustion products breaking the continuity of the metal. The carbon is burnt in the case of the burnt steel, the iron itself in the burnt iron.

The Total Solar Eclipse in India.—M. Janssen writes to the perpetual Secretary of the Paris Academy from Sholoor-Neilgherry:

—"I have just a moment since observed the eclipse with an admirable sky, and now, while still feeling the emotions caused by the splendid phenomenon I have witnessed, I address these few lines, etc. . . . . The result of my observations at Sholoor indicates, without any doubt, the solar origin of the corona, and the existence of matter beyond the chromosphere."

To M. Faye, the President, he writes:—"I have observed the corona, which I was unable to do in 1868, when my whole attention was given to the prominences. Nothing could be more beautiful or more luminous, with configurations, which exclude all possibility of an atmospheric terrestrial origin. The spectrum contains a very remarkable green ray, already announced, which is not continuous as already stated, and I find indications of the dark lines of the solar spectrum; notably the well known double line of sodium, D."

All of the observing parties, except those at Melbourne, seem to have been successful. The observations of Professors Lockyer and Resphigi both confirm those of Janssen, concerning the solar origin of the corona. The former gentleman, in a letter to *Nature*, remarks: "The composition and structure of a part of the corona have been forever set at rest, while we have seventeen photographs taken by instruments of the same power and pattern, to compare with each other."

Boiler Explosions!—Under this title appears, in the "*American Railway Times*" of February 17th, an article the tenor of which is not only to show how utterly useless it is to seek for the causes of steam boiler explosions by experimenting under varied conditions with boilers which have actually seen service—as has lately been done in the tests made at Sandy Hook; or by experimenting with apparatus especially designed to reproduce every possible contingency which the perverse ingenuity of "practical" engineers can invent, as in the classical experiments made years ago, by a committee of the ablest men in the Franklin Institute; but to explain, in addition, just how boiler explosions really occur.

The off-hand way in which this author disposes of the Sandy Hook trials as those of "so called" but deceived experts, and the elevated stand-point from which he pronounces that "we are gravely told in some of our school-books on natural philosophy that experiments were made by a committee of the Franklin Institute," are calculated to excite an unusual degree of curiosity to hear an exposition of the author's own views upon a subject which he handles "as one having authority and not as the scribes." It will therefore not seem

surprising that upon reaching the announcement, "Let us now see what *does* cause explosions," we were scarcely prepared to meet with a rehash of the old gas theory, so effectually and repeatedly exploded, in one form or another, time and again, that it is really surprising it should possess vitality enough to make its appearance in a fresh garb, whenever from any cause public attention is directed to the subject of boiler explosions.

The author's case is simply this:—Should a surface of boiler or flue, from insufficiency of water, become overheated, say to red heat, the steam will necessarily come in contact with this red hot surface and be decomposed into its elements; the oxygen will be appropriated by the iron, the hydrogen will be liberated. If now, by any means, as the starting of the engine, the hydrogen collected in the upper part of the boiler should be brought into contact with the oxide of iron heated to the same temperature as will decompose steam, the iron will be reduced, the gases again combining with explosive violence.

It would hardly be worth while to enter into the discussion of this so-often-disposed-of subject, were it not for the fact that the author subscribes himself as professor of a university, and treats his subject from a chemical and not from a mechanical stand-point. A few brief comments will be found below:

1st. It is gravely to be doubted, whether steam in contact with glowing metal surfaces can be decomposed into its elements, so long as water is present with it. In a steam boiler, the mechanical suspension of more or less water in the steam we conceive to be unavoidable; but be that as it may, so long as we have nothing but bare assertions to oppose the results obtained by the Franklin Institute committee, we prefer to adhere to the latter.

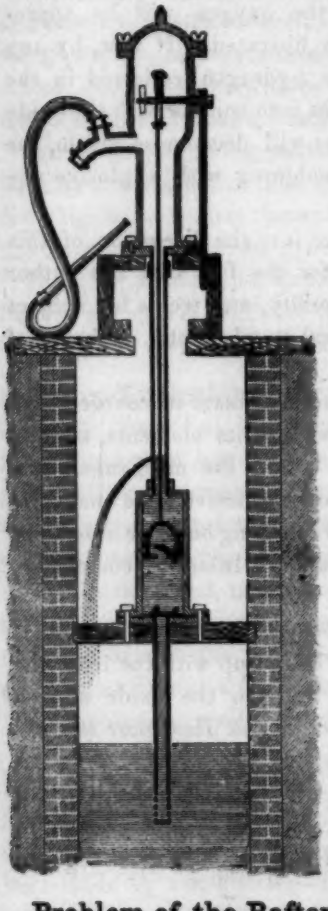
2d. Admitting that the steam is decomposed by the iron, that hydrogen is liberated and the oxygen bound up with the iron, the statement of the author that the contact between the oxide of iron and hydrogen, "*at the same temperature as will decompose steam*," will result in a reduction of the iron oxide, and a re-union of the gases with explosive force, is palpably incorrect, since it is asserted that, under exactly the same conditions in which iron is strong enough to rob the hydrogen of its oxygen the hydrogen is strong enough to take possession of it again.

3d. Even admitting this chemical paradox, it is impossible that the hydrogen should reduce the oxide of iron with explosive violence.

The assertion will be opposed by the repeated experience of every practical chemist.

The employment of hydrogen as a reducing agent for numerous metallic oxides is a matter constantly recurring in the laboratory, and this process, so far from taking place with explosive violence, on the contrary is often a tediously gradual one. The assertion, therefore, that hydrogen will produce so violent an action with iron oxide is unsupported by any fact known to the chemist, but is contrary to his almost every day experience.

While agreeing with the author that "the best judge of any science or art is a person who has made science or art his particular study," inquiring minds will be disposed to call for something more than mere statements to support even a theory as fascinating as his appears to be.



A Force and Lift Pump.—The accompanying figure represents a pump, manufactured by the American Pump Company, Philada., and exhibited at a late meeting of the Franklin Institute.

The pump for out-door work here represented, is secured to a plank or timber, and is connected by a pipe to the water to be lifted. The plunger rod is worked by a rocking shaft running through the side, instead of working, as ordinarily, through the top. The handle is attached to the outer end of shaft, thus permitting the top to be closed by a hinged lid, secured by thumb screws, and forming an air chamber. When this is off, the machine is a simple lift pump; when on, it is converted into a force pump, throwing a continuous stream with considerable force.

Problem of the Rafters.—Since the article on page 100 of the present volume of the *Journal* was published, I have found that Prof. Rankine, in his Civil Engineering article 179, page 292, has given the

correct formulas for this case. My formulas agree with his when the *notation* is so changed as to agree with each other. DR V. W.

Errata.—Page 104, second line from the bottom, for wxAB read wAB.

Page 106, second line from the bottom, the line *bf* referred to is not shown in Fig. 6.

Page 107, near the middle of the page in equation for compression, for Cos^2 read $Cos^2\theta$.

The Cost of Tunnelling.—The *London Times*, in a recent article, gives a tabulated statement of a number of the more important tunnelling enterprises, from which we learn that the cost per linear yard of the works below named were as given:

Mont Cenis, $975; the Kilsby, the Saltwood and the Bletchingley, the costliest of the English tunnels, cost $725, $590 and $360 respectively. That of Terre Noire (France) cost $475, and the Hoosac, in Massachusetts, has thus far averaged $940.

Adulteration of Aniline Colors.—The intense tinctorial power of the aniline dyes seems to offer irresistible temptation to dishonest dealers to imitate or adulterate them with worthless ingredients. A sample of fuchsine (an aniline red) lately placed in our hands by Dr. Genth was composed entirely of sugar crystals saturated with the coloring matter. To any one familiar with the peculiar arborescent appearance of the pure fuchsine particles, the sugar crystals, with their rhombic prisms, would betray the imposition at a glance; but without this knowledge the detection would be attended with some difficulty, since the color of both genuine and counterfeit samples is equally intense. One of the simplest methods to detect this and similar impositions is simply to digest a sample of the suspected substance in ether or absolute alcohol, when the coloring matter will be dissolved with ease, and the sugar, crystals, or wood fibre (which is also used for dishonest purposes) will remain undissolved.

Arsenic in Colored Carpetings.—Hallwachs* has found that not only green but also the red colored carpetings frequently contain arsenic. He particularly asserts that the brilliant dark red colors, now so greatly in demand, contain enormous quantities of this poisonous substance. The goods burned with the blue flame of arsenic, and gave its characteristic garlic odor. Enough of the color could be

* Gewerb. f. d. Grossh. Hessen., 169.

rubbed off with the finger to give a distinct precipitate of arsenic with the usual reagent, and in solution in hydrochloric acid covered some copper pieces with the greyish coating characteristic of the substance.

A Lecture Experiment.—V. Wartha describes a neat method of illustrating the presence of sulphur in illuminating gas. He places, on a platinum wire, a bead of carbonate of soda on the edge of the flame of a Bunsen burner for a minute, and obtains then, by partially cutting off the air supply, a small cone of light in the flame. Into this the bead is placed, and the sulphate and sulphite of soda previously formed is brought to the condition of sulphide of sodium by the reducing action of the glowing carbon particles. The bead is then crushed in a porcelain dish, and a solution of the nitro-prusside of sodium added, when the characteristic reaction of sulphur is readily obtained. The reaction is said to be more than fifty times as sensitive as that with silver, which is ordinarily used. A minute suffices to obtain it.

Litmus Paper as a Reagent.—A paper upon the sensitiveness of litmus paper in indicating the presence of alkalies or acids, has recently been published* by Mr. Chas. Bullock, from which it appears that a reaction may be obtained with one drop of 30 per ct. acetic acid in the following quantities of water: In 4 oz. it turns red immediately; in 6 oz., in half a minute; in 10 oz., turns red on edges in one-fourth minute, completely in one minute; in 13 oz., completely red in one and one-half minute; in 16 oz. the limit of distinct reaction is reached. With an alkali the following results were obtained: With one grain of andhyd. carb. soda in 32 oz. of water the bluing occurred in one minute; in 56 oz., in three minutes; in 64 oz., in four minutes; in 80 oz., in seven minutes; in 160 oz. of water the limit of distinct reaction is reached.

The Argentotype.—A photographic process called by its inventor, Mr. F. A. Wenderoth, of this city, by the above name, is in operation, and from the great beauty of the results promises to become largely introduced. The general outline of the process will be understood from the following description:

A carbon print is made in the ordinary way, by exposing a bichromated gelatin film beneath a negative. A silvered metallic plate is

* Am. Jour. of Pharmacy, Jan., 1872.

next taken, and rubbed with a sanded brush, to depolish the surface and heighten the effect of the picture. The plate, after cleansing, is laid on a sheet of paper, on a table containing diluted alcohol. The carbon point is now brought face down in contact with the plate, a paper sheet is laid upon it, and by a simple roller, the alcohols and air bubbles are forced from between plate and print, and the two made to adhere firmly. The plate with film is now immersed in water of about 100° F. and developed, leaving a film of varying thickness on the plate through which the lights are in the thin parts, and the shades in the thick insoluble parts. The character of the metallic surface gives a peculiar tone to the picture, and the shades may be varied by using colored gelatin.

To render his pictures more durable, Mr. Wenderoth attaches them by a simple method hermetically to glass plates. The same artist is operating a photo-zincographic process, which is new in some respects, an illustration of which we will shortly be able to give.

Formation of Ozone.—Dr. Pincus states that ozone is formed during the burning of hydrogen; and that if a flame of this gas is allowed to burn from a fine point, the smell of ozone can be distinctly recognized. This statement recalls to mind the announcement made some time since by Loew, of New York, that ozone might be obtained in sufficient quantity for purposes of lecture demonstration, by simply blowing the heated air on the edge of an ordinary Bunsen flame, with the aid of a glass tube, into a glass receiver, containing the ordinary reagent for testing an oxidizing agent—iodide of potassium, acetic acid and starch—when the blue coloration of the iodide of starch almost instantly makes its appearance. At the time, Loew's announcement met with some objectors, who sought to explain the phenomenon by assuming that the oxidizing process originated with certain oxidized nitrogen compounds formed by the heat of the flame. From the fact, however, which is well-known to chemists, that it is impossible to unite nitrogen and oxygen directly, by any means short of the electrical spark, the explanation of Loew would seem to be the correct one.

To Determine the Value of Aniline Colors.—Armand Müller suggests the use of collodionized glass plates upon which an alcoholic solution containing a known percentage of the color to be estimated is fixed, and compared with similar films containing certain known quantities of a normal color. By this process he declares it possible to determine the value of different colors with great nicety.

Utilization of Slag.—A method of utilizing slag, in use at the blast furnaces at Osnabrück, in Hanover, is to allow it to fall in a stream from a height of about eight feet into water. It is thus granulated into particles of the size of a bean. From the water tank it is lifted by an elevator into cars and conveyed away, to be used in ballasting the roads and railways. We have the authority of Mr. Brockbank for the assertion that the Bessemer slags of the hæmatite furnaces make an excellent concrete from the large per centage of lime contained therein.

Editorial Correspondence.

The item on page 75 of the present volume has elicited the following communication, which, of course, necessitates the omission of the term novel there applied to it.—Ed.

PHILADELPHIA, Jan. 27th, 1872.

W. H. WAHL, ESQ., *Secretary Franklin Institute, Philada.*

DEAR SIR,—The signal to warn train men standing on the tops of cars, on their approach to an overhead bridge, to which you alluded at the last meeting of the Institute as a novelty, was introduced upon the Pennsylvania Railroad in April, 1867, and is now in general use upon that road.

I am informed by Mr. T. J. Heizmann, engineer, who first introduced it, that about that time he saw a newspaper paragraph speaking of its use on a railroad in Connecticut, and its adoption on the Pennsylvania Railroad was suggested thereby. Yours, truly,

ENOCH LEWIS.

Civil and Mechanical Engineering.

THE LOCOMOTIVE ENGINE, AND PHILADELPHIA'S SHARE IN ITS EARLY IMPROVEMENTS.

By Joseph Harrison, Jr., M. E.*

Some persons care little or nothing for the past. Musty records and old things have no charm for them, and their lives seem centred in the one word, "Now." Perhaps they may be right in their abstract way of viewing the question, and they might well be pardoned for saying *cui bono*.

Others, again, omit nothing in their efforts to explore all that can possibly be reached of record or memorial, telling of the earlier days of the world on which we live, and of the doings of the inhabitants thereof. They never weary in lavishing time, trouble and expense, in following their favorite pursuit, and often are fully repaid, after long and laborious research, in the mere bringing to light of some trifling relic of may-be doubtful value, or some record not worth, perhaps, the time it has taken to secure it.

In the researches of the antiquary how little, however, is brought out of the inner workings of the individual minds which have evolved the beautiful and the practical in Art, in Science, and in Mechanism, even in comparatively recent days. It is the detail of their work that those interested in the subject so much desire, and do not find. They would know the ways and the means, and the chain of reasoning or experiment, whereby these early workers produced the results that are left to us. And how interesting is the little that has come down to our time.

The engineer, noting the curious things in bronze and in copper, exhumed at Pompeii, and gathered together in the Museo Borbonico at Naples, will linger near a small vessel for heating water, little more than a foot high, in which are combined nearly all the principles involved in the modern vertical steam boiler—fire-box, smoke-flue through the top, and fire-door at the side, all complete;—and strange to say, this little thing has a *water-grate*, made of small tubes crossing the fire-box at the bottom, an idea that has been patented twenty times over, in one shape or another, within the period of the history of the steam engine.

*This paper was written before the publication of a recent work on the early history of the Locomotive in the United States, by ——— Brown, and all that is stated herein, after Oliver Evans' time, is from personal observation. The author has not seen the work alluded to in this note. J. H.

The architect, looking at the faded drawings made many centuries ago, and still serving as a guide in the completion of that epic in stone, the wonderful Cathedral on the banks of the Rhine, at Cologne, is interested not only in the beautiful forms and proportions portrayed in these now dim lines, made by the architect whose name is still preserved to us, but in noting the changes and alterations that mark their gradual approach towards perfection, showing plainly that revision and variation from the original design, was as necessary then as now, if perfection was to be achieved. These are even still extant in record if not in drawings; examples of Roman architecture indicating the same slow approach towards a more perfect ending, in the erection of the monuments that now excite our wonder, built to adorn the Capitol of the world more than two thousand years ago.

Knowing what we know, and seeing what we see of improvement and advancement in mechanical and engineering science and art all around us, how interesting it is to look at the first condensing steam-engine made by James Watt, and the little locomotive "Rocket," of George and Robert Stephenson, both so carefully preserved in the South Kensington Museum in London.

The history of a most remarkable machine, now so necessary in our daily wants, had its real commencement but forty years ago, and yet much that is exceedingly interesting in the detail of its early introduction and improvement is unknown to this generation, and before many years all those who labored at its beginning, and who only can tell the story of its early progress towards its present perfection from their personal knowledge, will have passed away.

To prevent this loss in part, an effort will be made in the following pages, without going too much into technical detail, to bring together some facts in connection with the early and very important work of Philadelphia Mechanics and Engineers in the origination and in the development of the improvements in the LOCOMOTIVE ENGINE.

In the opening part of an article printed in a supplement to the Encyclopædia Brittanica, 1824, may be found the following: "RAILWAYS.—A species of road or carriage way, in which the track of the carriage wheels being laid with bars or rails of wood, stone or metal, the carriage is more easily drawn over this smooth surface than over an ordinary road." And further, in the same article, after alluding to the early history of rail-ways in Great Britain, and touching on the chief lines then in use, the article continues: "From these accounts of the chief rail-ways in England and Wales, it will appear that this

species of inland carriage is principally applicable where trade is considerable, and the length of the conveyance short, and is chiefly useful in transporting the mineral products of the kingdom from the mines to the nearest land or water communication, whether sea, river or canal. Attempts have been made to bring it into more general use, but without success, and it is only in particular circumstances that navigation, with the aid of locks or inclined planes to surmount the elevations, will not present a more convenient medium for an extended trade.

"South Wales, however, presents an example where the trade being great, and also chiefly descending, the country rugged, and the supply of water scant, rail-ways have been adopted with complete success, and have been found, in some cases at least, equal to canals in point of economy and dispatch." After further discussing the topic, the conclusion of the article is as follows: "On some of the rail-ways near Newcastle the wagons are drawn by a steam-engine placed on a wagon by itself, the wheels of which are driven by the engine, and, acting on a rack laid along the rail-way, impel forward the engine and the attached wagons. In some cases, the wheels of the wagon operate without rack-work, by the mere friction between them and the rail. The steam-engines employed for this purpose are of the high pressure kind, these requiring no condensing apparatus."

"But this application of steam has not yet arrived at such perfection as to have brought it into general use."

When it is considered that but a generation and a half has passed since its publication, the above reads strangely in the light of our present knowledge and experience. It is noteworthy, too, that in the article from which the above extracts have been taken, there is not one word in relation to the transportation of passengers by railroad, nor is the name of "LOCOMOTIVE," since become so distinguished, once used.

During the five years following the publication of the above, little was done towards the improvement of the motive power for working the railroads of Great Britain, the only country in which they were used. In 1829, when the Liverpool and Manchester Railroad (the pioneer of a new system which has since attained such tremendous proportions) was well advanced towards completion, the locomotive was so unimportant an agent, that it was even then not easy to decide the question of motive power for working that important line. The locomotive had its friends in the Stephensons, father and son,

—in Hackworth, Braithwaite and Erickson, Trevethick and others. A plan for placing fixed steam engines at intervals along the line to draw the trains by endless ropes running over pulleys, had its supporters. Horses were looked to as a safe means to fall back upon when all else should fail. A machine to use horse power was even thought of, and was afterwards built, in which the propelling horses were carried on the carriage that was to be used for drawing the train.

During the year 1828 it became imperative, on the part of the Directors of the Liverpool and Manchester Railway, to decide in some way the question of motive power, and in that year a deputation of this body "was appointed to visit the railways of Northumberland and Durham, where the different varieties of motive power were most extensively practised." This deputation returned from this mission without coming to any conclusion as to which class of motive power would most conduce to their interests. They *did*, however, decide "that horse-power would be inapplicable for the great traffic that was anticipated upon the new line."

By this decision the question was narrowed down to the locomotive engine (then gradually becoming the favorite) and the fixed engine. This latter device was known to be clumsy in its management, and difficult to manage where a large traffic was to be carried on, or where it was of primary importance that a greatly increased speed must be aimed at. Little scope, therefore, was left in the fixed engine system for improvement tending to meet these essentials, and little could be expected. At this point in this most important controversy, it was suggested that the surest way to bring out the merits of the locomotive system, was to excite competition on the part of its advocates by the offer of a premium or reward for the best locomotive engine. In the spring of 1829, and in accordance with this idea, first enunciated by Mr. Harrison, a member of the Board, it was decided by the Directors of the Liverpool and Manchester Railway, to make this premium £500, to be contended for under conditions to be fixed by the Company.

The very important conclusions which soon resulted from the competition induced by the above offer, in the rapid improvement of the locomotive engine, formed a new era, not only in *their* history, but in the importance of railways generally. The conditions upon which the premium was offered was in part as follows:

"RAILWAY OFFICE, LIVERPOOL,
25th of April, 1829.

"STIPULATIONS AND CONDITIONS

On which the Directors of the Liverpool and Manchester Railway offer a premium of £500, for the most improved locomotive engine.

"1st. The said engine must 'effectually consume its own smoke,' according to Railway Act. 7th Geo. IV.

"2nd. The engine, if it weighs six tons, must be capable of drawing after it, day by day, on a well constructed railway, on a level plane, a train of carriages of a gross weight of *twenty tons*, including the tender and water tank, at the rate of *ten miles* per hour, with a pressure of steam on the boiler of *fifty pounds* to the square inch.

"8th. The price of the engine that may be accepted is not to exceed £550, delivered on the railway; and any engine not approved is to be taken back by the owner."

The following engines were entered for the prize:

The "Novelty," by Braithwaite and Erickson.
" "Rocket," by Robert Stephenson.
" "Sans Pareil," by Timothy Hackworth.
" "Perseverance," by Mr. Burstall.

All these engines had distinct principles in their construction, the most important of which being in the plan, and in the steam generating properties of the boilers.

After a fair test of all the locomotives competing in accordance with the regulations fixed, the prize was easily won by the "Rocket," built by George and Robert Stephenson; this engine having fulfilled, in some respects, more than all the requirements of the trial.

It is remarkable that the "Rocket," in all or nearly all of the essentials that go toward making the locomotive what it is, was as complete as the engine of our day. Its weight was but 3 tons, 1 cwt. From the success achieved by the "Rocket" at Liverpool, the locomotive engine took the place it now fills so perfectly, as the great motor for land transportation. All other devices were at once abandoned.

The type of locomotive established by the success of the "Rocket" became the then standard in England, and the Directors of the Liverpool and Manchester Railway lost no time in stocking their railway with engines, mainly after this model.

With this preliminary, it is now the purpose of this article to tell the early story of the locomotive in Philadelphia, and an effort will be made to show how great a share the minds and hands of our engineers and

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mechanics have had in the improvement and development of (without doubt) the most important agent of this or any other age. In telling this story completely, it will be necessary to take a retrospect and go back to the year 1786.

In that year, Oliver Evans, a man who deserves at this day all honor at our hands as one of Philadelphia's noblest sons, "petitioned the Legislature of Pennsylvania for the exclusive right to use his improvements in flouring mills and steam carriages in his native State. In the year following he presented the same petition to the Legislature of Maryland. In the former case he was only successful so far as to obtain the privilege for the mill improvements, his representations respecting steam carriages savoring too much of insanity to deserve notice."

"He was more fortunate in Maryland, for although the steam project was laughed at, yet one of his friends, a member, very judiciously observed that the grant could injure no one, for he did not think that any man in the world had ever thought of such a thing before. He therefore wished the encouragemeut might be afforded, as there was a prospect of its producing something useful." The exclusive privilege was granted, and after this Mr. Evans considered himself bound in honor to the State of Maryland to produce a steam carriage as soon as his means would permit him.

To Oliver Evans must be awarded the credit of having built and put in operation the first practically useful high-pressure steam engine, using steam at 100 pounds pressure to the square inch, or more, and dispensing with the complicated condensing apparatus of Watt. The high-pressure engine of Evans had advantages for us in its greater simplicity and cheapness, and ever since his day it has continued the standard steam engine for land purposes in this country.

English writers have tried to detract from the fame of Oliver Evans, but it is well known that early in his engineering life he sent drawings and specifications of his engines, &c., to England by the hands of Mr. Joseph Stacy Sampson, of Boston. It is well known also that these drawings, &c., were shown to and copied by engineers in England, and from this period dates the introduction into Europe of the first really useful high-pressure steam engine, now so generally applied to locomotive and other purposes.

Basing his hopes of success on the use of the high-pressure engine in his steam-carriage, Oliver Evans, notwithstanding the opposition and even the derision of his best friends, and of almost every one,

made earnest efforts in the beginning of this century to carry out his design for building his favorite machine, but without success. He had a good friend in Mr. Robert Patterson, then Professor of Mathematics in the University of Pennsylvania, who recommended the plan as highly worthy of notice, and who wished to see it tried. Evans' plans were shown to Mr. B. H. Latrobe, a scientific gentleman of great eminence in his day, who publicly pronounced them chimerical, and who attempted to demonstrate their absurdity in his report to the American Philosophical Society on "*Steam Engines*," in which he also undertook to show the impossibility of making steamboats useful.

In Mr. Latrobe's report, Mr. Evans was said to be seized with the "*steam mania*," which was no doubt most true. To the credit of our then and now most learned Society, the portion of Mr. Latrobe's report which reflected so harshly upon Mr. Evans was rejected, the members conceiving that they had no right to set up their opinions as an obstacle in the way of an effort towards improvements that might prove valuable for transport on land. The Society did, however, admit in the report the strictures on steamboats.

Oliver Evans never succeeded in constructing a steam-carriage such as he had contemplated. It was commenced, and unaided he spent much time and money in fruitless efforts to complete it. Finding himself likely to be impoverished if he persisted in the scheme, he finally abandoned it, and devoted his time thereafter to the manufacture of his high-pressure steam engine and his improved milling machinery. Previous, however, to the final abandonment of his favorite project, Oliver Evans, on the 25th of September, 1804, submitted to the Lancaster Turnpike Company a statement of the cost of and probable profits of a steam-carriage to carry *one hundred* barrels of flour *fifty* miles in twenty-four hours, tending to show also that one such carriage would make more nett profit on a good turnpike road than ten wagons drawn by five horses each. He offered to build a steam-carriage at a very low price. Evans' statement to the Turnpike Company closed as follows: "It is too much for an individual to put in operation every improvement which he may invent. I have no doubt but that my engines will propel boats against the currents of the Mississippi, and wagons on turnpike roads, with great profit. I now call upon those whose interest it is to carry this invention into effect." Oliver Evans, in the early part of 1804, came nearest to realizing his favorite idea, in obtaining an order from the Board of Health of Philadelphia to construct at his foundry (a mile and a half from the

water) a dredging machine for cleaning docks, the first one ever contrived for dredging by steam, now so common.

To this machine Evans gave the name of "Oructor Amphibolis," or Amphibious Digger, and he determined, when it was completed, to propel it from his workshop to the Schuylkill River, which was successfully done, to the astonishment of a crowd of people gathered together to see it fail. When launched, a paddle-wheel, previously arranged, was applied to the stern, and again it was propelled by steam to the Delaware, leaving all vessels half way behind in the trip, the wind being ahead. This result Evans hoped would have settled the minds of doubters as to the value of steam as a *motor* on land and water. But his attempt at moving so great a weight on land was ridiculed, no allowance being made by the *hinderers* of that day for the disproportion of power to load,—rudeness in applying the force of steam for its propulsion, or for the ill form of the boat. A rude cut of the "Oructor Amphibolis" is still extant, which shows a common scow, mounted on four wooden wheels, with power applied to the whole number of the wheels by the use of leathern belts. Evans, after this experiment, willing to meet the question in any way, silenced the *carpers* around him by offering a wager, that for $3000 he would make a steam carriage that would run on a level road as swift as the fastest horse they could produce. His bet met with no takers. This movement by steam power of Oliver Evans' dredging machine on land was, without any doubt, the first application of steam to a carriage in America, and in fact the first locomotive engine. It was a more important experiment than any that had preceded it, anywhere, in the same direction.

Oliver Evans' conceptions respecting the power of steam, many of them practically exemplified by him, reflects great credit on his sagacity as an engineer, and many of his predictions in regard to its great value, particularly for land transport, may well be termed prophetic.

In the early part of this century he publicly stated that "The time will come when people will travel in stages moved by steam engines, from city to city, almost as fast as birds fly,—fifteen or twenty miles an hour. Passing through the air with such velocity, changing the scene in such rapid succession, will be the most exhilarating exercise." "*A steam carriage will set out from Washington in the morning,—the passengers will breakfast in Baltimore,—dine in Philadelphia, and sup in New York the same day.*" "To accomplish this, two sets of railways will be required, laid so nearly level as not to deviate more

than two degrees from a horizontal line,—made of wood or iron, or smooth paths of broken stone or gravel, with a rail to guide the carriages, so that they may pass each other in different directions, and travel by night as well as day." Much stress is laid upon these early efforts of Oliver Evans towards the introduction of steam for land and water transportation, and much space has been given here to set them forth. With no light to guide him (for it is fair to suppose that he knew nothing of the little that had been done up to his day in Europe), how his trumpet-tones ring out in the words above quoted, compared with the "uncertain sound" made by the English engineers in 1829. *They*, with a quarter of a century or more of later experience, during which period much had been done to improve and develope the locomotive engine, hesitated and doubted in their course. *He*, with no misgivings as to the result, and with no dimmed vision, saw with prophetic eyes all that we now see. To *him* the future picture, in all its grandeur and importance, glowed in broad sunlight. In the history of these efforts of Oliver Evans it is noteworthy, and most creditable to our sister State of Maryland, that that Commonwealth extended to him the first public encouragement in his steam-carriage project. Again our enterprising neighbor was first in the field since become so important, for we find that in March, 1827, the State of Maryland chartered the first railway company in America, and in 1828 her citizens commenced the construction of the Baltimore and Ohio Railway, aiming to cross the Alleghenies; certainly the greatest railway scheme that had been thought of up to that date, and now, in its completed state, a triumph of railway engineering. To this first effort to make a great railway in the United States, and its influence upon the history of the locomotive in Philadelphia, reference will be made hereafter.

Oliver Evans died in 1819 and his plans for a steam carriage died with him, and although he produced nothing practically useful in the great idea of his life, he has left behind him an enduring monument in his grain and flour machinery.

[Note. The improvements of Oliver Evans in grinding flour, as described in his "Young Millwrights Guide," (a standard authority at this day on the subject of milling), changed the whole system of handling grain and its products. The principles and, in many respects, the arrangements in detail of the great grain elevators used so extensively at the present day, came originally from the teeming brain of Evans. In the first edition of the Young Millwrights Guide,

published eighty years ago, an engraving may be seen of an elevator unloading a vessel at the river side, and conveying the grain to an upper granary on the wharf, just as it is done to-day. It is painful to read Evans' own story of his struggles against the prejudiced and doubting men of his time in his efforts to introduce his improved milling machinery. Those who were ultimately most benefited by his inventions were his most persistent opponents. But he triumphed at last in this, although failing to get his steam carriage into use.]

The materials for the history of the next attempt at making a steam carriage in Philadelphia, eight or nine years after the death of Oliver Evans, are not very full. At this period a steam carriage to run on a common road was projected by some parties in our city whose names cannot now be easily reached. This steam carriage was built at the small engineering establishment of Nicholas and James Johnson, then doing business in Penn street, in the old district of Kensington, just above Cohocsink Creek.

An eye witness of its construction, and who saw it running under steam on several of its trials, describes it as an oddly arranged and rudely constructed machine. It is believed to have had but a single cylinder, set horizontally, with connecting-rod attachment to a single crank at the middle of the driving axle. Its two driving wheels were made of wood, the same as an ordinary road wagon, and were of large diameter, certainly not less than eight feet. It had two smaller wheels in front, arranged in the usual manner of an ordinary road wagon, for guiding the movement of the machine. It had an upright boiler hung on behind, shaped like a huge bottle, the smoke-pipe coming out through the centre at top, formed the neck of the bottle. On its trials, made on the unpaved streets of the neighborhood in which it was built, this steam carriage showed an evident lack of boiler as well as cylinder power. It would, however, run continuously for some time and surmount considerable elevations in the roads. Its safety valve was held down by a weight and lever, and it was somewhat amusing to see the puff, puff, puff, of the safety valve as the machine jolted over the rough street. This was before the days of spring balances for holding down the safety valves of locomotives. This engine was sometimes a little unmanageable in the steering apparatus, and on one of its trials, in coming over the High bridge and turning up Brown street, its course could not be changed quick enough, and before it could be stopped it had mounted the curbstone, smashing the awning-posts, making a demonstration against the

bulk window of a house at the south west corner of Brown and Oak streets.

After this mishap it was not seen on the streets again, nor is it known what ultimately became of it. This last effort may be classed, in some respects no doubt, with what Oliver Evans promised in his mind to carry out, and it is very evident that up to its time no great amount of knowledge or of practical or theoretical skill had been brought to bear upon the construction of locomotives in Philadelphia. No books were as yet published in America describing the locomotive, or telling what had been done in land transport by steam in Europe. The trials on the Liverpool and Manchester railway in 1829 had not been made, and a better result could have hardly been expected than this recorded above.

With the wonderful success of the "Rocket" in October, 1829, the attention of our engineers and capitalists was strongly turned towards this new revelation in land transport, that had so suddenly flashed upon the world. It was a matter of the greatest importance to us, with our rich lands everywhere teeming with produce, the producers meanwhile crying aloud for better means to get their harvests to market, and for getting our people, too, more speedily from point to point, that we should know more of this new thing, and if it fulfilled its promise, to get the advantage of it as soon as possible. It did not take long to come to a decision that railways *must* be built, and that speedily. It has been seen that Maryland took the lead, and had her great road well under way before others States looked the question fairly in the face. South Carolina followed the lead of Maryland, and granted a charter at an early period to the South Carolina Railway, intending to cross the whole breadth of the State, and ultimately aiming to reach the far west. Signs of railway movement were seen in Pennsylvania, Delaware and New Jersey, and in New York and New England. The Columbia railroad (a State work) was projected in Pennsylvania at this time, and the Philadelphia, Germantown and Norristown Railroad was begun in Philadelphia. New Jersey had chartered and commenced her road from Camden to Amboy, and little Delaware, ahead of all the States north and east of her, had two miles of the New Castle and Frenchtown Railroad ready for use on the 4th of July, 1831. The South Carolina Railroad was amongst the first to encourage the manufacture of American locomotives, and Mr. Horatio Allen, a gentleman honored still as a good citizen and as one of the first engineers in the country, designed and had built, in 1830 and '31, at the West Point foundry, in New York, the two first locomotives, it is be-

lieved that were ever ordered and made in the United States for regular railroad traffic.

The engines did good service on the South Carolina Railroad, and it is curious to note that Mr. Allen's locomotive embodied in this construction every valuable point of the "Fairlie" engine, now making so much noise in England. These points being the use of a vibrating truck at both ends with cylinders thereon, fire-box in the middle between two cylinders, with flues from fire-box to each end of the boiler, double smoke-box and double chimney, with fire-door at the side of fire-box, flexible steam and exhaust pipe, &c.

[NOTE. The first locomotive ever run on a railroad in America was undoubtedly the "Lion," one of two engines built at Stourbridge, in England, under the direction of Mr. Horatio Allen, and imported into this country in the autumn of 1829, for the Delaware and Hudson Railroad in the State of New York. Mr. Allen, in describing its first movement, says that he was the only person upon the engine at the time, and he (living still) made the first trip by steam on an American railroad. The "Lion" built before the "Rocket," had vertical cylinders, arranged somewhat after the manner of the old style of Killingworth engine, with four driving wheels all connected. The boiler of this engine approached somewhat to the locomotive boiler of the present day, in having a fire-box with five flues leading to the smoke-box, this latter feature being, in fact, the first step towards the present multi-tubular boiler.]

The Directors of the Baltimore and Ohio Railroad in January, 1831, by advice of Mr. Jonathan Knight, of Pennsylvania, still taking the lead in the railroad movement, and with the desire to encourage American skill, adopted the same plan that had been so successfully carried out at Liverpool in 1829, offered a premium of $4,000 for the best American locomotive.

At this period in this history more mind and more practical skill has been brought out in Philadelphia, looking towards the improvement of the locomotive engine. In March, 1830, Col. Stephen H. Long, of the United States Topographical Engineers, a gentleman of high scientific culture, and noted for his originality, obtained a charter from the State of Pennsylvania, incorporating the "American Steam Carriage Company," and soon thereafter commenced the construction of a locomotive in Philadelphia. This engine was designed somewhat after the then recently improved locomotives made in England, but had several original points.

This first engine of Col. Long was placed, when finished, upon the Newcastle and Frenchtown Railroad, and the Hon. Wm. D. Lewis has furnished the following account of its trial at various times on that road with which he at that time was connected in an official capacity.

COL. LONG'S LOCOMOTIVE.

"On the 4th of July, 1831, two miles of the rails being laid on the Newcastle and Frenchtown Railroad, Col. Long made trial on it of his locomotive, which weighed about 3½ tons. The first effort was not a success, the failure being attributed to lack of capacity to furnish a sufficient supply of steam. It would go well enough for a while, but the steam could not be kept up. The next day the Colonel had better luck; his engine then going to the end of our rails and back, drawing two passenger cars packed with people, (say 70 or 80,) with apparent ease, and it had fifty pounds of steam at the end of the experiment.

"The Colonel, however, was not satisfied with it, and the machine was brought to Philadelphia again, and a new boiler was constructed for it at Rush & Muhlenburgh's works at Bush-hill. This engine was again taken to Newcastle and tried upon the road but it again failed. It would go very well for a time, but on the 31st of October, 1831, a pipe was burst and it became disabled. This being repaired, two days thereafter another trial was made, but with equal want of success, which was ascribed to lack of power, as well as of specific gravity. Alone, this engine went very well, and rapidly, say at the rate of 25 miles an hour, but it would not draw a satisfactory burden.

"Soon after the above date, Col. Long removed his engine from the road, and I do not know what became of it afterwards." Mr. Lewis adds, "The above memoranda I now enclose of the trials of Col. Long's locomotive in 1831, are made from a book in which all the facts I give you were set down contemporaneously with their occurrence." This unsuccessful attempt of Col. Long was, up to its date, much the most important movement that had yet been made in Philadelphia towards the improvement of the locomotive, and as such it deserves special notice. It was furthermore not without its value in inducing him to pursue the subject to much better results. Had Col. Long more faithfully copied the English engine of his day, he would have had better success in his first effort; but he, as with all our Philadelphia engineers and mechanics at that time, and in the succeeding years, aimed at making an American locomotive.

Whilst Col. Long was engaged in the construction of his engine,

the late Matthias W. Baldwin, a name that has since become so famous in the history of the improvements and in the manufacture of the locomotive in Philadelphia, was engaged in making a model locomotive for the Philadelphia Museum. In this work Mr. Baldwin was assisted by that highly eminent practical mechanic and engineer, the late Franklin Peale, then Manager of the Museum.

To gratify the curiosity of the public to know more of this new thing, this little engine was placed upon a track laid around the rooms of the Museum, in what was then the Arcade, in Chestnut street above Sixth, and where it was first put in operation on April 25th, 1831. It made the circuit of the Museum rooms many times during the day and evening for several months, drawing behind it two miniature passenger cars, with seats in each for four persons, but often carrying twice that number, in a manner highly gratifying to the public, who attended in crowds to witness for the first time in this city and State the effect of steam in railroad transportation.

The desire to *know* more of, and the necessity to *have* as speedily as possible, this new power, soon became a paramount question in the Middle, Northern and Eastern States of the Union.

The reward of $4000 offered for the best American Locomotive by the Directors of the Baltimore and Ohio Railroad, brought out many competitors, and in after years several very curious specimens of locomotive engineering might be seen in one of the shops of this road. An eye-witness of these efforts in 1834, describes one which sported two walking-beams precisely like the river steamers of the present day. Mr. Phineas Davis, of York, Pennsylvania, bore off the prize offered by the Baltimore and Ohio Railroad, and his engine was the only one that survived the trial. With the Peter Cooper upright tubular boiler adapted thereto, this locomotive of Mr. Davis became for several years the type of engine for the road upon which it won its fame, and to this day some of these Grasshopper or Crab engines, as they are sometimes called, may be seen doing good service at the Camden street Station, in Baltimore.*

*Previous to the competition on the Baltimore Railroad, Mr. Peter Cooper, the well-known New York Philanthropist of the present day, sent to Baltimore a small engine not larger than an ordinary hand-car. This little locomotive had an upright tubular boiler, (no doubt the first of its kind,) which developed such good steam-making qualities as to induce Mr. Phineas Davis to purchase the Cooper patent right, and boilers of this kind were used by Mr. Davis in the locomotives built by him, subsequent to the competitive trial on the Baltimore and Ohio Railroad.

REPORT OF WATER-WHEEL TESTS AT LOWELL AND OTHER PLACES.

By JAMES EMERSON, Lowell, Mass.

Early in the past season, notice was given that the experiments at the Lowell Testing Flume would close for the season with November; but at that date twenty wheels remained untried, and the experiments were continued until the close of the year; then, to decide whether the percentage of a wheel remained the same under different heads, I went to Ballston Spa, N. Y., and Mount Holly, N. J., and tested wheels that had previously been tested here. The results obtained seem to show that much higher percentage can be obtained under a low than a high head.

A description of all the wheels that I have tested would require too much room, and I will only refer to the peculiarities of a few. There seems to be a growing mania with wheel-builders to construct combination, or double wheels. The idea, old in itself, seems to have been revived by James Leffel at a time when it was difficult to find a really good wheel. The merits of his wheel, together with the indomitable energy of its builders, have rendered it one of the leading wheels in the country and too well known to require description here.

The combination shown in fig. 3 is upon an entirely different principle—a "perpetual motion," if successful. This combination was placed in a curb similar to the one patented by W. S. Davis, only the gates all opened at once. Mr. Wynkoop claimed that the velocity of the water, by direct action, operated the upper wheel, then the *weight* of the water acted upon the re-action wheel below, thus obtaining double power from the water used; and, strange as it may seem, college professors, engineers, high-school teachers and officials of various grades were found who were willing to endorse such claims; and a circular was published and circulated, containing the names of a score or more of influential persons, who stated that they had seen the wheel in operation, and believed it gave one hundred and seventy-five if not two hundred per cent. of the power of the water used. When the combination was tested here it discharged so much more water than was expected, that the weir was too short and the water ran over the sides of the testing pit. The percentage due from the water passing the weir without allowance for that escaping over the sides of the pit, is given with the other wheels. Since testing the combination, I have received applications from three different States, by different parties,

for terms for testing identically the same combination. An engraving of the Wynkoop, together with the results of test sent in reply, has in each case closed the correspondence.

A combination of the "Barker Mill," with a Fourneyron wheel, as represented (fig. 4), also has admirers. Three Mexicans from the City of Mexico came here to have such a combination tested, but abandoned it before doing so. The same combination has been placed in a mill within a few miles of this city, but the inventor has not yet concluded to enlarge his building facilities.

B. J. Barber of Ballston Spa, N. Y., has made a combination that works well (fig. 5); so well, indeed, as to cause manufacturers to think seriously of exchanging the expensive Fourneyron wheels as built by Mr. Boyden for it. The combination consists of a wheel like the Warren, (which was a favorite fifteen years ago, and now may be seen back of many a mill in New England, where it has been thrown to make room for better wheels,) and a re-action wheel underneath for the purpose of utilizing the remaining power of the water after it has passed the upper wheel. This is a theory upon which much time and money has been expended. Mr. Barber is working upon a more decisive plan than theorists generally do, for he has built a testing flume and procured complete testing apparatus in order to work understandingly.

Stilwell & Bierce Manufacturing Company of Dayton, Ohio, have also done the same in order to make the Eclipse (double) Turbine one of the best.

Gardiner Cox also furnished a wheel which he called double; it consisted of a core with a Jonval wheel, around it, at the bottom, the buckets being continued by sheet iron spirals around the core to its top, forming a twelve-threaded screw; the pitch being twelve degrees from line of rotation.

The curb represented in fig. 6 was tried, to ascertain whether better "part gate" results could be obtained by opening a certain number of gates, from two to sixteen, than by opening the whole, proportionally; with the wheels tried, the results were not favorable, but the principle would seem to be correct, for in testing a Houston wheel, with some of the openings stopped with blocks of wood, it will be seen that very high results were obtained for the proportion of water used.

Much has been said about highly finished wheels being sent here for trial. There is little foundation for such rumors. In 1869 the Messrs. Leffel sent wheels that were constructed for the purpose, as

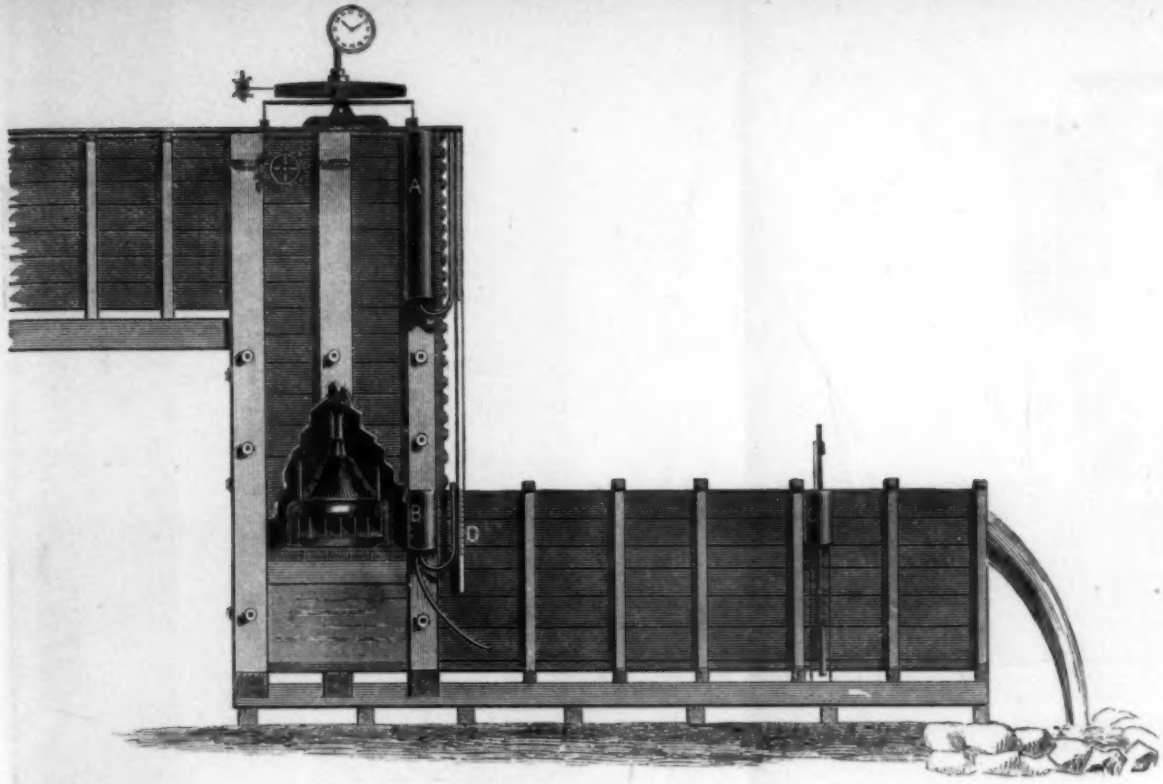


Fig. 1.

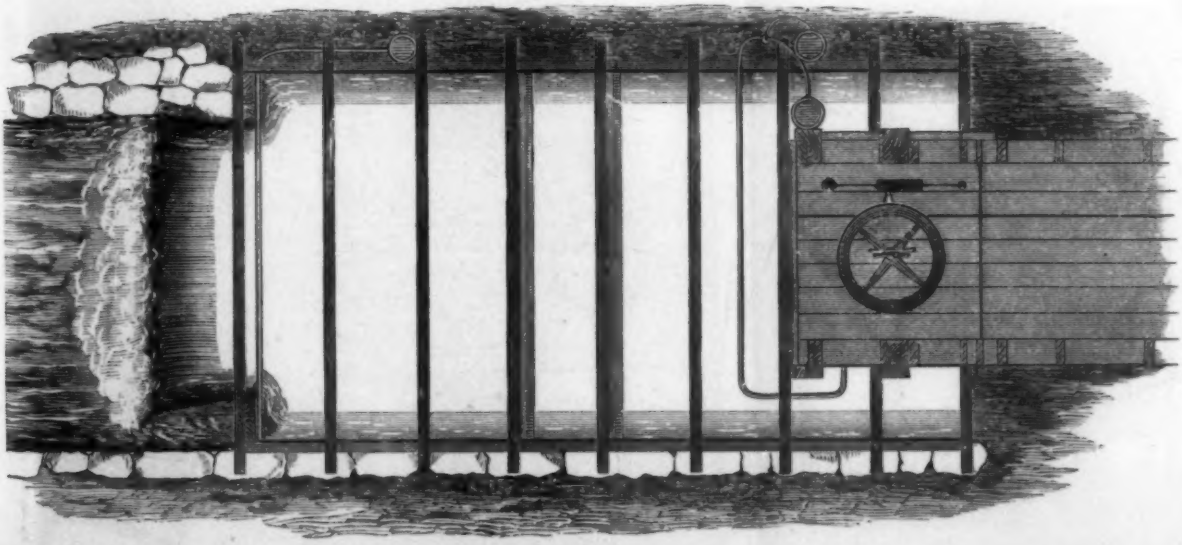


Fig. 2.

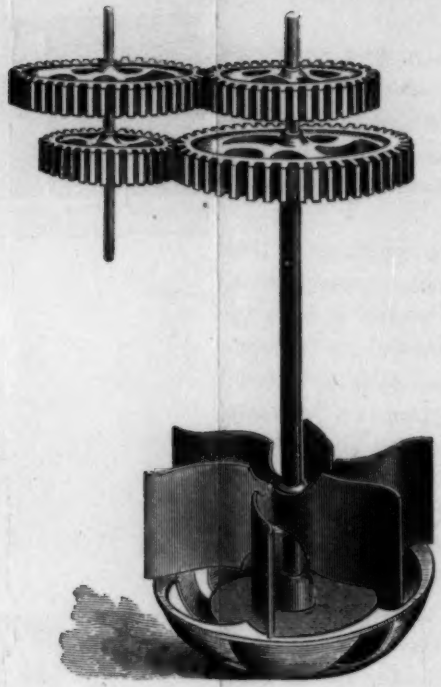


Fig 3.

The two wheels combined with gears at the top, like the Wynkoop.

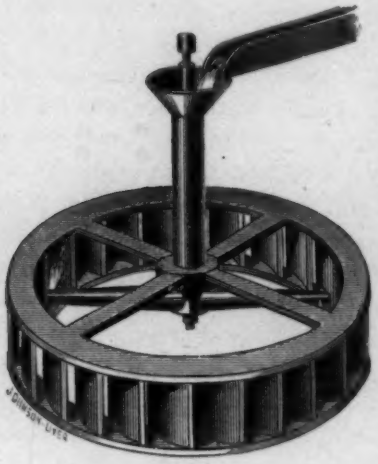


Fig. 4.

Fig. 5.

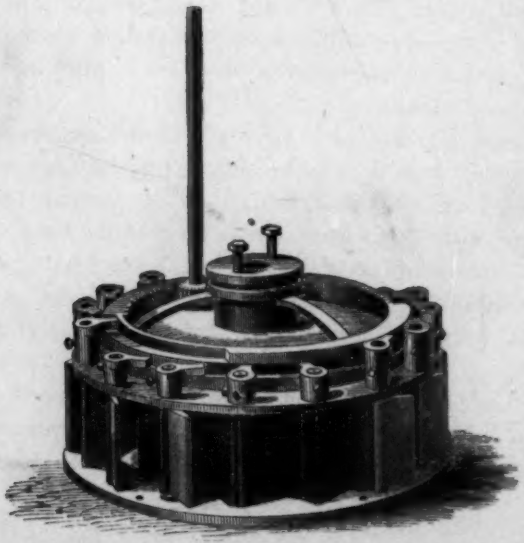


Fig. 6.

they had a right to do under the conditions imposed, and, as a rule, those sending wheels have been very fair, and, most certainly, the wheels that have given the best results have not been those of the best finish. It is quite common for some manufacturers to say that "little reliance can be placed in reports of tests;" such statements have a very injurious influence, and if there is any cause for such, it rests with themselves. The comparative merits of any wheel may be determined at a testing flume as perfectly as groceries can be weighed, but the cause for discrepancies is that builders seldom construct two wheels exactly alike, so that if Mr. Smith has a "Samson Turbine" that gives satisfactory results, there is no certainty that Mr. Jones will get one of that make that will do the same, and here may be found the cause why references are of little value. The better class of builders, feeling the inconveniences arising from such a system, are having their wheels tested, not only to determine their merits, but experimentally for improvement, while another class sell their wheels on the reputation of some well-known wheel that has been tested, but the same builder while experimenting will vary more than twenty per cent., consequently, manufacturers should understand that a resemblance is no guarantee of merit, and their only chance for obtaining a reliable wheel is to buy of responsible parties who are ready, at any time, to prove by actual trial that their wheels are what they are represented to be; a strict observance of such a rule would add at least twenty-five per cent. useful effect to the water power of Massachusetts.

An examination of the results obtained while testing N. F. Burnham's wheel will show the accuracy with which it can be done. The wheel was first tested, the shaft being made rigid with faced couplings bolted together; it was then taken out, the face couplings exchanged for clutch couplings, then tested again, afterwards taken out of the flume, then taken apart, the buckets filled to an edge, faced couplings again fitted on and the shaft where it worked in the upper bearing filed smaller, then tested the third time.

Stetson's first wheel, tested 1870, was tested the past season to decide whether a decked Flume is equally as effective as an open flume; it will be seen that the highest result was obtained in the decked flume, but it had four hundred pounds less weight of shafting to carry.

In making the experiments to determine the loss of power in transmission through gears, mitre gears twenty-seven inches in diameter, five-inch face, fifty-seven teeth, were used on wheel and "jack-shaft,"

the last being six feet in length and three inches in diameter, a spur gear twenty-four inches in diameter, four and one-half inch face, forty-four teeth, was secured upon the "jack-shaft,' which worked into another gear of the same size upon a second horizontal shaft, same size and and length as the first, the second representing the main line of shafting through a mill, both horizontal shafts worked in common babbited bearings. The dynamometer was placed upon the end of the shaft representing the main line, and the wheel tested through the two pairs of gears; the second shaft was then removed, the dynamometer applied to the end of the "jack-shaft," and the wheel was then tested through the mitre gears only, then the "jack-shaft" was removed, the gear taken from the top of the wheel shaft, the dynamometer applied at the same point and the wheel tested in the usual manner; the tests upon the wheel shaft and the shaft representing the main line were perfectly steady and reliable. The test upon the "jack-shaft" was made at noon under a higher head, and the end of the shaft was too small for the hub of the dynamometer, causing it to run eccentrically, and the test was not so good. I propose the coming season to make a more thorough trial of such tests with differently proportioned gears.

The reported part gate tests were taken when the wheels were running at about the same speed as when the best whole gate results were obtained; and three-fourths, one-half, one-fourth, &c., gate designate the proportions of water discharged and not the openings of the gate.

TEST OF WHEEL TO DETERMINE LOSS OF POWER IN TRANSMISSION THROUGH GEARS.

Through a pair of mitre and a pair of spurs, as described, the brake being placed upon the end of the second horizontal shaft, then upon the first horizontal shaft, then upon the wheel shaft.

Tests.	Head.	Revolutions.	Horse Power.	Percentage.
1st test.	16·03 feet.	160 per minute.	26·55	75·90
2d "	16·64 "	172 " "	27·36	74.80
3d "	16·08 "	168 " "	26·72	77·40

OUTSIDE TESTS FOR POWER ONLY.

Chase Wheel, Orange, Mass. Have tested four different wheels; one guaranteed to give 30 horse power, gave 11·8; but as a general

thing they gave about the power rated, using enormous quantities of water. The tables in their circulars are computed at about 90 per cent., and the discharge of the wheel is estimated from its openings, but the centrifugal force causes a discharge considerably larger than would pass through the wheel when it is at rest (ascertained by actual trial). The wheel, under favorable circumstances, gives about 50 per cent. of the power of the water used.

Whitney Wheel, at South Lancaster, Mass. Tabled horse power under 7-foot head, 66·17. Actual, as per test, 35·65.

Whitney Four-Feet Scroll Wheel, at C. B. Richmond's Mill, Lowell, Mass. Guaranteed, under 8-foot head, to give 20 horse power. Actual, as per test, under 8-foot 5-inch head, 11·22. Four-Feet Flume Wheel, same mill, 8-foot head, gave 15 horse power.

Five-Feet Blake Wheel, at same mill. Guaranteed, under 8-foot head, to give 30 horse power. Actual, as per test, under 7-foot 8-inch head, 15.

Seventy-two-Inch Reynold's, at Williamstown, Mass. Tabled, under 12-foot 3-inch head, to give 152 horse power. Actual, as per test, 76·97. Nominal percentage, as per table, 95. Actual, about 50.

July 26, 1871, I assisted in testing the same wheel again, after submerging it. Dynamometer placed upon wheel shaft, 12-foot head gave 88·30 horse power. Saw no reason to change my opinion about the percentage of that wheel, at any rate.

Breast Wheel, at North Adams, Mass. Diameter, 16 feet; length, 22; head, 14. Best result, 52·67 horse power.

I have, in the first part of my Report, alluded to tests made at Ballston Spa, N. Y., and Mount Holly, N. J. Those tests show very high results, and if the correction in Mr. Francis' formula for velocity of water approaching the weir is reliable, then low falls give proportionally much the best results. I have never seen experiments made where the brake worked so smoothly as at Mount Holly. Under the six-foot head, the wheel ran so steady that the hydraulic regulator upon the scale beam was hardly required, and when the wheel was running at its best speed, the water near the weir might have been used for a mirror, it was running so smooth.

At Ballston Spa, Mr. Barber's wheel gave, with the upper wheel tested alone, five per cent. higher results than at Lowell; while with the two combined, the best result was about seventy-nine and a half; this was under eight-feet head. The test of the combined wheels at Lowell can not be considered reliable, because it was bound in the

stuffing-box. The Risdon wheel was also bound slightly in the upper bearing at Lowell, causing a loss perhaps of one per cent., while it run perfectly free at Mount Holly, where it gave 84·24 as highest result. Now, it must be understood that I consider the Risdon or Barber wheel exceptional, for that is far from being the case, for I believe the other wheels tested would show the same proportional results under low heads, and to determine that point, I shall immediately construct a new flume that will enable me to test all wheels under from six to eighteen-foot head, and I propose to have my flume large enough to test five foot wheels. I test wheels that give good percentage that I should not consider so good for practical use as others that perhaps show in my Report less favorably; but it is not expected that I should discriminate, but give figures only, as I do; but it is for the interest of those using wheels that a matter of such importance should be definitely determined; for that reason I make the following proposition: The first day of September next I will have flume and apparatus complete for testing large wheels under varying heads, the trial to be open to all, each wheel-builder to furnish one or more forty-eight or fifty-inch wheel, to be delivered at my flume upon the day named, and each party to be there ready to choose a committee competent to examine and witness the test of each wheel, and let the decision of that committee be published throughout the country; and I here call upon the Messrs. Swain, Leffel, Bodine, Bryson, Houston, Stetson, Burnham, Libby, Risdon, Wheeler, Cook, Barber and others, to demonstrate, by a thorough competitive trial, where the conditions are the same for all, that they have faith in their assertions that *their wheel is the best.*

Particulars for terms, conditions, &c., may be had upon application.
Lowell, Mass., Box 502, *February* 1*st*, 1872.

EXPERIMENTAL STEAM BOILER EXPLOSIONS.

Discussion of the third experiment at Sandy Hook, New York.

By Prof. R. H. Thurston.

The violence with which the third boiler, experimented upon at Sandy Hook, exploded, has raised a doubt in the minds of many engineers whether some extraordinary and unfamiliar cause may not have operated in the production of such astonishing effects. No positive proof of the non-existence of such causes can be given, but the following considerations will at least indicate that we may find,

NAME.	Size.	REMARKS.	Ft. Head.	PERCENTAGE OF PART GATE.					WHOLE GATE	
				¼	½	⅝	¾	⅞	Horse-Power.	Per cent.
Swain	42 in.	In "Quarter turn"	14·25	.....	.....	.....	.....	.....	63·00	82·2
"	36	" " "	15·10	.....	.....	.....	.....	.....	46·39	77·56
"	36	Wood Flume	15·10	13·10	43·20	.....	67·00	71·90	45·40	74·60
"	30	" "	15·41	.....	47·30	59·20	59·20	72·80	36·40	76·17
"	24	"Quarter turn"	16·66	.....	54·17	.....	72·30	.....	24·26	77·69
"	24	Wood Flume	15·89	.....	55·40	.....	67 60	72·90	18 07	72·60
Leffel	40	Iron Case, extra finish, expressly for test	.....	.....	.....	.....	.....	.....	42·00	79·70
Common finish	30½	Wood Flume	15·40	.....	59·10	64·80	66·40	67·50	31·82	74·80
Bodine Jonval	35	Iron Case	14·70	.....	.....	.....	.....	.....	34·00	75·90
Bryson Turret	42	Wood Flume	14·00	.....	.....	.....	.....	.....	.....	75·14
" "	30	Iron Case	14·51	.....	.....	.....	.....	.....	26·00	74·10
Tice	30	Wood Flume	.....	.....	.....	.....	.....	.....	.....	.....
Houston	30	" "	8·50	.....	.....	.....	.....	.....	11·25	82·30
"	35	" "	15·50	.....	.....	.....	.....	.....	41·28	79·94
Second	35	Iron Case. Ice in flume and on weir	14 95	.....	.....	.....	.....	.....	37·36	77·50
"	30	" " " " "	15·80	.....	.....	.....	.....	.....	26·81	78·80
Third	30	Wood Flume	15·00	.....	45·50	48·60	60·90	65·00	29·45	81·21
"	30	With four guides stopped with blocks of wood	.....	.....	.....	.....	.....	.....	22·72	76·00
"	30	With seven, or one-half the openings stopped, discharging a little more than half water	.....	.....	.....	.....	.....	.....	15·76	70·30
Trullinger	30	Brass Buckets, bound in curb and burst	15·69	.....	.....	.....	.....	.....	19 31	50·64
Second	30	Iron Buckets. No reliable part gate	15·80	.....	.....	.....	.....	.....	27·78	70·37
Kindleberger	25		15·30	.....	.....	.....	.....	.....	25·22	62·46
Stetson	30	Open Flume—1870	15·79	.....	.....	.....	71·60	.....	25·72	78·46
"	30	In Decked Flume—1871	15·09	.....	56·84	.....	72·83	.....	26·13	79·26
Second	30	Deeper, greater discharge	16 17	.....	.....	.....	.....	.....	29·32	74·10
Same	30	Suspended by the neck	16·07	.....	55·76	.....	70·36	.....	27·17	75·70
Another	30	Like the above, with one bucket less	16·00	.....	55 41	.....	71·79	.....	29 61	77·40
Same	30	Suspended by the neck	14·76	.....	.....	.....	.....	.....	26·82	79·08
Upham	36	Wood Flume, bound in curb & crumbled to pieces	15 99	.....	.....	.....	.....	.....	18·32	52 08
Second	36	" " Same curb bound badly	15·59	.....	.....	.....	.....	.....	22·06	58·82
"	36	Scroll	15·85	.....	.....	.....	.....	.....	26·53	72·84
Third	36	Wood Flume. Bound in curb	15·64	.....	.....	.....	.....	.....	17·11	53 78
Fourth	36	" " Less No. of buckets than the above	16·52	.....	.....	.....	.....	.....	18·96	6 03
Fifth	36	Scroll. Scroll 1¼ in. in depth less than the above	16·38	.....	.....	.....	.....	.....	20·05	64·09
Sixth	36	Less buckets. The 4 wheels made with plates at top	16·38	.....	.....	.....	.....	.....	20·05	64·09
Seventh	36	First Scroll Wheel made with arms, openings between, tested in reduced scroll	16·31	.....	.....	.....	.....	.....	22·28	67 42
Luther	30	Scroll Wheel	16·10	.....	.....	.....	.....	.....	18·91	70·51
"	16	Discharged so little water that it would not carry brake	.....	.....	.....	.....	.....	.....	.....	.....
Wheeler	36		15·65	.....	.....	.....	66·90	.....	27·73	74·50
Second	36		16·10	.....	61·56	.....	70 62	.....	29·63	74·46
Third	36		15·61	.....	.....	.....	.....	.....	25·56	67·61
Whitney	30		15·28	.....	.....	.....	.....	.....	23·48	67·13
Second	30	Greater discharge	15·71	.....	.....	.....	.....	.....	23·79	.....
Third	30	Three less buckets. Results better than with more	15·66	.....	.....	.....	.....	.....	27·07	.....
"	18	Sliding gates	15·15	.....	.....	.....	.....	.....	11·70	.....
Wynkoop	42		15·12	.....	.....	.....	.....	.....	36·22	55·89
"	42	Cut hole in draft tube. Large quantity of water escaped unmeasured	10·90	.....	.....	.....	.....	.....	21·88	62·00
Davis	36	See his patent curb. Wheel burst after running a few minutes	16·30	.....	.....	.....	.....	.....	30·97	66 90
Second	36	Curb tried for part gate tests, but nothing seemed gained by the arrangement	15·17	.....	.....	.....	.....	.....	36·42	68 56
Third	36	Like the Warren	15·48	.....	.....	.....	.....	.....	33·30	63·46
Tyler	42	In use six years	15·20	.....	.....	.....	.....	.....	34·90	55·56
"	30	New, none sold	15·70	.....	38·11	.....	59·08	.....	27·13	73·83
Second	30	Old style, wrought iron buckets	15·69	.....	.....	.....	.....	.....	25·91	67·04
Third	30	Old style, cast whole, cast iron buckets	15·53	.....	.....	.....	.....	.....	25·66	67·01
Burnham	24		15·40	.....	48·16	.....	64·63	71·95	19·71	77·09
"	36¾	Tested with rigid shaft	15·27	.....	45·60	54·60	.....	71·00	42 18	78·60
"	36¾	Clutch couplings used	15·57	.....	.....	.....	.....	.....	43·27	78·50
"	36¾	Rigid couplings. Buckets and shaft filed	15 42	.....	.....	.....	.....	.....	43·27	79·20
Busby	36		14·97	15 92	43·08	.....	59·51	63·25	24·40	66·13
Cook	30	Buckets changeable	15·70	.....	56·78	.....	67·92	.....	27·53	73·11
Second	30	Double buckets	14·71	.....	66·10	.....	74·90	73·20	28·14	72·40
Bastion	30	Intended to be like Houston's	16·25	.....	26 51	.....	48·30	.....	18·04	66 75
Second	30	Wicket Gate	16·10	.....	.....	.....	31·40	.....	27·64	69·70
Third	30	" "	16 00	.....	9·35	.....	34·60	.....	24·67	70·10
Risdon	30	With diffuser on. Diffuser was a flaring tube underneath	15·79	.....	.....	.....	.....	.....	27·53	77·09
"	30	Diffuser off	15 98	.....	37·41	.....	66·59	.....	27·42	77·14
"	36		15·92	.....	41·17	58·08	69·02	76·12	36·57	78·71
Eclipse	24	Experimental, to determine effect of changes	.....	.....	.....	.....	.....	.....	.....	.....
Barber	30	Combination—two wheels—test of upper wheel alone	15·97	.....	.....	.....	.....	.....	24·78	66·36
"	30	Test of the two combined	15·03	.....	.....	.....	.....	.....	26·36	68·43
Teller	30	Double wheel	14·78	.....	.....	.....	.....	.....	27·27	64·50
"	24	" "	16·11	.....	.....	.....	.....	.....	20·64	53·80
Libby	30	An inverted Houston's	15 36	.....	11·50	.....	41·42	48·88	25·78	75·61
Second	30		15·94	.....	.....	.....	.....	.....	21·05	64·80
Third	30		15·42	.....	.....	.....	.....	.....	27·13	77·80
Gardiner Cox	30	Double spiral and Jonval	14·87	.....	45·90	.....	64·39	69·50	20·11	70·00
Thompson	30	Somewhat like Houston's	15·87	.....	53·90	.....	68 90	69·10	24·50	72·00

in well understood and certainly existing causes, ample power to produce all of the effects noted.

The steam boiler referred to weighed 40,000 pounds, and contained about 30,000 pounds of water and 150 pounds of steam, all of which had a temperature of 301° Fahr., when, at the moment before explosion, the steam pressure was 53½ pounds above that of the atmosphere.

When the explosion took place, the whole mass at once liberated its heat, until it had cooled down to the temperature of vapor under the pressure of the atmosphere.

In this act the water gave off $30{,}000 \times 89° = 2{,}670{,}000$ British thermal units, and the steam lost the difference between its total heat at 301° and that of 212° Fahr., or $150 \times 27{\cdot}2° = 4080$ thermal units. The sum, $2{,}670{,}000 + 4080 = 2{,}674{,}080$ thermal units has an equivalent in mechanical energy of $2{,}674{,}080 \times 772 = 2{,}064{,}389{,}760$ foot-pounds, and this was sufficient to have raised the whole boiler and contents, weighing 70,000 pounds, to a height of 29,491.282 feet—*more than five miles.* This represents the *maximum* possible effect.

The *least* effect would have been produced had the liberation of heat and the production of additional quantities of steam, within the mass of water and at its surface, been so sluggish as to have given no assistance in propelling the fragments of the ruptured boiler,—the whole destructive work being done by the simple expansion of the steam which filled the steam spaces.

The total amount of mechanical energy set free from the steam alone, was $4{,}080 \times 772 = 3{,}149{,}760$ foot-pounds, or sufficient to raise the whole boiler through a space of 78·74 feet, and, water included, 44.99 feet. Owing to the greater inertia of the lower part of the boiler, and particularly of its inelastic burden of water, the principal part of this work was undoubtedly performed upon the upper portion and steam chimney of the boiler, weighing, probably, 6,000 pounds; and, if entirely expended in this direction, the work thus done was equivalent to raising this 6,000 pounds to a height of 525 feet.

This latter case is capable of treatment in quite a different way from the above. As the boiler was completely torn in pieces, the steam must have expanded pretty equally in all directions, except where checked in its downward movement, and may probably be treated as if forming a rapidly expanding hemisphere of vapor, its centre being in the steam space of the boiler.

The expansion of this hemisphere would have continued until the

tension of the steam was reduced to that of the surrounding atmosphere, and would have continued through a mean distance, as given by an approximate estimate, of 4·5 feet. The mean pressure would be 25 pounds above the atmosphere nearly.

The area of cross-section of the steam drum was 4,071 square inches, and $4{,}071 \times 25 \times 4{\cdot}5 = 457{,}987{\cdot}5$ foot-pounds, the amount of work done in its projection.

The weight of the steam drum, which was one-quarter inch thick, six feet diameter, and eight feet eight inches high, was, with its braces, 2,500 pounds, and $457{,}987{\cdot}5 \div 2{,}500 = 183{\cdot}2$, the height, in feet, to which the drum might have been thrown by the simple expansion of the confined steam. In fact, the steam drum had attached to it, when found after the explosion, a considerable part of the boiler top, which, being comparatively light, and being acted upon by similar pressures, must have considerably accelerated, rather than retarded, its ascent.

Still another calculation may be based upon the observed effects of this explosion. The steam drum was observed to rise at a high "angle of elevation," and fell at a distance of 450 feet from the starting point.

If this angle of elevation was 60°—and the general impression was that it was not less—the height due to the range, 450 feet, neglecting the resistance of the air, would have been

$$h = \frac{R}{2 \sin 2\alpha} = \frac{450}{2 \times .866} = 260 \text{ feet.}$$

The retarding effect of the atmosphere causes our figure to be somewhat less than the true value, and it may be more nearly correct to take 275 feet as the height due to the noted range. The work done in raising the steam drum to this height was 687,500 foot-pounds, and the pressure which, acting through a space of 4·5 feet upon the base, would correspond to this amount of work, is 37·5 pounds.

This figure is in excess of the real pressure required, for the reason, as already stated, that a part of the shell was attached to the steam drum, assisting in its propulsion to an extent which is a matter of mere conjecture, and which not improbably reduces the given pressure several pounds.

The actual height of ascent of this piece was variously estimated by the spectators at from 200 to 400 feet, and, by one individual at least, even considerably higher. As, in such cases, heights are usually over-estimated, the lower figure is most likely to be nearest the truth.

It would be impossible to make the last two estimates so closely approximate to accuracy as to entitle them to great confidence, and the other calculations are merely estimates of improbable actual effects.

The writer is, however, inclined to conclude :—

1st. That it is very certain that the energy of this explosion, and all of its tremendous effects, were principally due to the simple expansion of a mass of steam suddenly liberated, at a moderate pressure, by the general disruption of a steam boiler of very uniform but feeble strength.

2d. That, *in this case*, the liberation of steam throughout the mass of water contained in the boiler, and which took place by the evaporation of one pound in every thirteen of the water, and which resulted in setting free nearly seventy thousand cubic feet of steam, would not seem to have taken place promptly enough to greatly intensify the effects of the explosion.

3d. It would seem very doubtful whether Zerah Colburn's hypothesis—which explains the violent rupture of steam boilers, by the supposition that the steam liberated from the mass of water, in cases of explosion, carries with it, and violently projects against those parts of the shell immediately adjacent to the point of primary rupture, large quantities of water which, by their impact, extend the break and increase the destructive effect, can have had an illustration in case under consideration.

We have no right to conclude that such an action as Colburn described may not occur in many cases of explosion; on the contrary, the simple experiment described in all text-books on Natural Philosophy, in which water in a closed vessel, and near the boiling point, is caused to enter into violent ebullition by the reduction of pressure following the application of cold to the upper part of the vessel, exhibits very plainly the probability of an action taking place such as Colburn describes.

The expulsion of the contents of a bottle of effervescent wine or fermented liquor, which occurs frequently on drawing the cork, is another illustration of such a phenomenon. There can hardly be a doubt that cases do occur in which the same action greatly increases the destructive effect of boiler explosions.

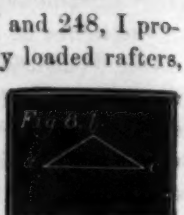
In the case above considered, it seems probable that the effect of the explosion was somewhat intensified by a generation of steam at and near the exterior of the mass of water contained in the boiler, but not by the expansion of steam formed near the centre of the mass.

Stevens' Institute of Technology, Hoboken, N. J., Jan., 1871.

PROBLEM OF THE RAFTERS.

By John C. Trautwine, Civ. Eng.

In my Civil Engineer's Pocket Book, pages 247 and 248, I proposed a mode of finding the strains on the uniformly loaded rafters, and upon the tie-beam of the simple roof truss, *a b c*. I also there stated that I considered the mode given by Professor Rankine, on page 470 of his Civil Engineering, edition of 1862, and by other authorities, as entirely erroneous and unsafe. In a foot-note on page 248, I gave the principle upon which my mode was based; and on page 252 I expressed the wish that "Professor de Volson Wood, or some one equally proficient in the higher branches of theoretical mechanics, would consider it worthy of an examination and opinion." Prof. Wood has kindly complied; and in the last number of the "Journal," under the head, "Problem of the Rafters," has shown that both the authorities and myself are in error; I to a greater extent than they, but fortunately on the safe side; whereas their method is, as I asserted, unsafe. My mode would be correct only for the action of a load placed at the top of the rafters, and omitting the weight of the rafters themselves. I am, however, inclined to think that Prof. Wood himself has also partially fallen into an error, to which allusion will be made farther on.



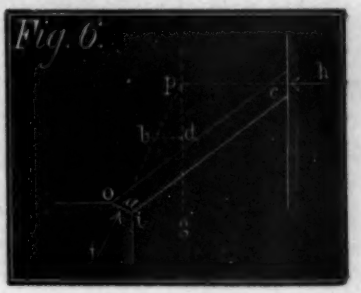
Unfortunately his paper is too mathematical for my perusal; and I can only express my regret that he did not employ such plain English as myself and readers generally understand, and which is amply sufficient for the elucidation of all such purely elementary principles. Still I learn from it that I am wrong in assuming that the loaded truss is to be regarded merely as so much weight resting upon its two supporting walls; but that it must be considered in the way pointed out for a single rafter in Art. 38 and fig. 22½ of my page 468, as given by Tredgold (see his Carpentry, edition of 1828, Art. 35, fig. 19), and later by Prof. Rankine.

However paradoxical it may at first sight appear that, so far as regards the strains, we must not primarily consider the truss as so much load pressing vertically upon its two supporting walls, yet such is the fact; and Prof. Wood has conferred a favor upon not only myself, but the profession in general, by directing attention to its application to truss, *a b c*. It is certainly strange that although the correct principle has been so long known, and so frequently employed in illustrating

the strains upon a single isolated rafter, yet it has invariably been overlooked when treating upon the two rafters of the simple truss; to each of which it applies *in precisely the same manner* as to the single one.

The correct method is thus expressed on my page 468:

"Let *a c*, figure 22½, (fig. 6) be a beam; its foot resting on *o i*, and its head, *c*, merely *leaning against* a smooth *vertical* wall; and whether *a c* be unloaded, or whether it supports a load placed in any manner upon it or suspended from it, let the vertical line which passes through the centre of gravity of the beam and its load (both of which are supposed to be known) be represented by *p g*. The beam and its load may be regarded as a single body, acted upon and kept at rest by three forces, namely, its own gravity or weight, the force *h* at *c*, and the force *f* at *a*. No other forces act on it. Now, gravity acts vertically only, and in the case before us it may all be regarded as acting in the line *p g*. The force at *c* can act only at right angles to the surface or joint at that place (see Art. 19); and, since the joint is vertical, the force, *h*, must be horizontal, or along *h p*. The question now is, how to find the direction of the third force, *f*. To do this we must avail ourselves of the principle that when three forces which are not parallel to each other hold a body at rest, or in equilibrium, as these three forces hold the beam, *a c*, their directions all tend to or from one point, which is either at the centre of gravity of the body or in a vertical line passing through said centre. Hence, since the vertical direction, *p g*, of the force of gravity of the body, and the direction, *h p*, of the force, *h*, meet at *p*, therefore the direction, *f p*, of the force, *f*, must also meet there. Hence, we have only to draw a line, *f p*, in order to find the required direction. A post intended to support the end, *a*, of the beam, should have the position *f a*; and the joint, *o i*, should be at right angles to *f a*, and not to *a c*, as might at first be supposed from figs. 13 and 16 of Art. 32, in which the weight of the beams is not considered."



"Having found the directions of the three forces in fig. 22½, it only remains to find their amounts. To do this, we already have one of them given, namely, gravity, or the weight of the beam and its load; and we know that they must be in proportion to the sides of the tri-

angle drawn parallel to their directions. Consequently, if on the vertical direction, *p g*, we lay off by scale any portion whatever, as *p d*, to represent the force of gravity, then will the horizontal side of the triangle, *p d b*, represent by the same scale the horizontal pressure at *c;* and the side, *b p*, the oblique pressure at *a*. The horizontal pressure at the foot is equal to that at the head of the beam. It is, of course, included in the oblique pressure, *f*, which is compounded of said horizontal force and of the vertical force at *a*. The vertical force is equal to the weight of the beam and its load, none of which is sustained at *c*, nor can be so long as the joint at the head and wall is vertical."

The *p a* of fig. 22½ must be used, instead of the *r a* on the figure of my page 247, to express the direction and amount of pressure at the foot of each rafter; and *p c* instead of my *r h* for the horizontal forces at their heads and feet.

This correct process always makes the horizontal pressure at the head of the uniformly loaded rafter of the simple truss, *a b c*, or the equal horizontal pull upon the tie-beam at its foot, precisely one-half of that given by my incorrect process.* It also makes the pressure, *p a*, at the foot of each rafter, less than mine, in the same proportion that *p a* in any given case is shorter than the rafter, *c a*, itself.

The point in which I now differ from Prof. Wood is this: I consider that the strain at the heads of the rafters is purely horizontal, and that there is no strain whatever in the direction *c a*, fig. 22½, or *o c* of this figure, of the length of a uniformly loaded rafter; whereas he and all the authorities maintain that there is such a strain at its head.

* In a foot-note to my page 259 I express the belief (based upon the same incorrect reasoning) that the authorities are altogether mistaken about the additional strain produced on the tie-rod of a truss when the rod is raised in the center instead of being horizontal. It follows from the above that I am wrong in this matter also, my proposed mode of finding the entire strain on a raised tie being in excess except for the action of a load at the top of the rafters, and omitting their weight. The authorities, also, I imagine, are necessarily mistaken here, as well as in the above case of their supposed longitudinal strains along the uniformly loaded rafters of the simple truss, *a b c*. If so, it follows that nothing reliable has hitherto been written on this subject.

I, with many others, should be glad to see this matter of raised tie-bars for uniformly loaded rafters treated in familiar language, aided by diagrams. *This* question becomes complicated by the necessity for recognizing a force in the direction *p b* of the first figure, in *addition* to one along the rafters, produced by raising the tie-bar.

If so, it must extend all the way to the foot; and we should have the weight of the rafter in the preceding figure equivalent, not to its two components, *h p* and *p o* alone, but to them and a third force in the direction of the rafter; and this I conceive to be inadmissible.

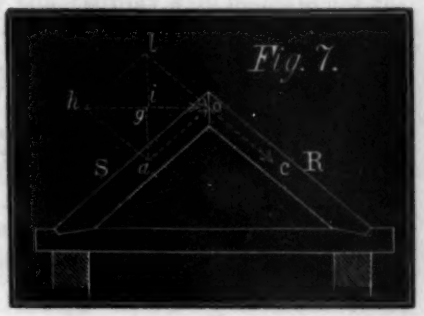


Fig. 7.

Prof. Wood reasons thus: The horizontal force, *h o*, pressing against the head of the rafter, R, may be conceived to be replaced by its two components, *l o* and *a o;* and *therefore* there is a strain, *o c*, equal to *l o*, at the head of the rafter. I, on the other hand, imagine that if, instead of the horizontal force, *h o*, we should apply the force, *l o*, *alone*, there would result, of course, a pressure, *o c*, along the rafter; but the moment we apply the other component, *a o*, at the same time, the direction of *l o* changes; and *l o* combining with *a o*, the two form a single new force, *h o*, the direction of which is *wholly horizontal*. The force, *l o*, may be conceived to be compounded of two forces equal to *li* and *io;* and the force, *a o*, of two equal to *a g* and *g o*. Now, if the two forces, *l o* and *a o*, be applied at the same point, *o*, at the same time, as substitutes for the single horizontal force, *h o*, I hold that their two equal vertical components, *l i* and *a g*, will re-act against or mutually *destroy* each other, leaving only the horizontal components, *i o* and *g o* (which are together equal to *h o*) to press as one single force against the rafter at *o*. In the same manner an opposite horizontal force equal to *h o* presses against the head of the rafter, S.

On my page 458, in Remarks 3 and 4, and in the Remark on page 450, I have endeavored to explain my views respecting this *mutual destruction* of *l i* and *a g* in the above figure in all cases of the conversion of two component forces into one resultant. I conceive that two components produce the same effect as their resultant, simply because equal portions of the two components *destroy* each other, so that the *remaining portions* actually *are* the resultant. In this I believe I am alone, for all writers appear to express the same views as Prof. Wood, and maintain that two components lose none of their energy by being applied at the same point at the same time. If I am wrong I shall be glad to be set right. My only desire in all such matters is to elicit *the truth*.

KEOKUK AND HAMILTON BRIDGE.

By Joseph S. Smith, Resident Engineer.

Organization.—February 13th, 1865, articles of incorporation for the construction of a railroad and wagon bridge were drawn up and approved under the name of the "Hancock County Bridge Company," with the following incorporators: Alexander Sympson, George Edmunds, Jr., Francis M. Corby, William A. Patterson, Hiram G. Ferris, Robert W. McClaughry, Andrew J. Griffith, Bryant T. Schofield and Phineas Kimball, Jr. Under this Act the company were privileged to bridge the Mississippi river at some point between the cities of Nauvoo and Warsaw, Hancock County, Illinois, to the Iowa shore, within the jurisdiction of the State of Illinois, and to commence operations within two years and complete the bridge within twenty years. Previous to this an Act was passed by the General Assembly of the State of Iowa, authorizing the construction of railroad bridges across the Missisippi and Missouri rivers, and was approved April 5th, 1864.

On January 15th, 1866, under the general incorporation law of the State of Iowa of 1851, Hugh T. Reid, James F. Cox, David W. Kilbourne, Robert F. Bower, Henry Strong, Smith Hamill, Wm. Leighton, Guy Wells, Carlton H. Perry, Henry H. Love, William Thompson and George C. Anderson incorporated themselves under the name of the Keokuk and Hamilton Mississippi Bridge Company, for the purpose of building a bridge across the Mississippi river as a railroad, wagon and foot passenger bridge, at or near the city of Keokuk, Lee County, Iowa, to a point at or near the city of Hamilton, Hancock County, Illinois, with power to unite with any bridge company chartered in the State of Illinois, with a capital stock of $1,000,000.

Under an Act of Congress of July 25th, 1866, bridges were authorized to be constructed at several points on the Mississippi and Missouri rivers, and established as Post Roads, of the number the Keokuk and Hamilton bridge.

Matters relating to a bridge at this point had now reached a stage when it became necessary to know the cost of the undertaking. A preliminary survey under the auspices of the Toledo, Wabash and Western Railway Co. had been made previous to1867, without leading to any definite results. In March, 1867, surveys were made by James W. Otley, Esq., Chief Engineer of the Des Moines Valley

Railroad, under the directions of Thomas Curtis Clark, Esq., then Engineer-in-Chief of the construction of the Quincy Railroad bridge. From this survey, preliminary plans were made and submitted to the city authorities of Keokuk early in 1868, upon which an ordinance, granting the right of way across the Levee, together with other privileges relating to the Union Depot Grounds, was passed and approved May 25th, 1868. Final plans, estimates and reports were submitted by Thomas Curtis Clarke, Esq., to the Directors of the Keokuk and Hamilton Mississippi Bridge Company in June, 1868.

On August 1st, 1868, the Hancock Co. B. Co. and the K. and H. Miss. B. Co. were consolidated under the name of the Keokuk and Hamilton Bridge Company, with the following Board of Directors: Hugh T. Reid, Carlton H. Perry, Wm. Leighton, David W. Kilbourne, Hugh W. Sample, Howard W. Perry, Hambden Buel, George W. McCrary and George E. Kilbourne, with a capital stock of $900,000, with power to raise it to $1,000,000.

The following were elected officers of the consolidated Company: Hugh T. Reid, President; Carlton H. Perry, Vice-President; Wm. Leighton, Secretary; Thomas Gilman, New York, Treasurer. Eastern capitalists were now solicited to undertake the construction of the bridge, and early in 1869 contracts were entered into with Andrew Carnegie and associates of Pennsylvania for its construction, to be commenced within thirty days and completed by the 1st January, 1870; based upon the plans of J. H. Linville, Esq., Civil Engineer of Philadelphia, as Chief Engineer for the bridge Co., with Thomas C. Clarke, Esq., C. E., late of the Quincy R. R. Bridge, as Consulting Engineer.

Mr. Joseph S. Smith, Resident Engineer in charge, together with his assistants, arrived on the ground early in March, 1869, together with the contractors for the substructure, Messrs. Quinn and Raynor, with their foremen and laborers. Having visited and examined several quarries for stone, contracts were closed with the Sonora Quarry Co., situated near Nauvoo, Hancock Co., Ills., it being the only quarry, within reasonable distance, so developed as to guarantee a supply as rapidly as would be required for the due completion of the masonry within the specified time. This stone is a magnesian limestone or dolomite, not difficult to work, but tough and durable, weighing about 148 lbs. per cubic foot. It has been thoroughly tested by geologists and others, and its use approved for the foundations of the State Capitol at Springfield, Illinois. That for the piers was nearly

all prepared during the season of 1869, and received further test by standing exposed until the building season of 1870.

Engineering.—Whilst the contractor was providing a steamer for the purpose of towing flat boats, derricks and other machinery, and all material to push the work rapidly, a final location of the bridge line was made, and its length across the river determined. A base line 3302.955 feet in length was established on the eastern shore, and carefully measured twice before the water got so high, (already covering portions of the base line about waist deep,) as to prevent the angles being taken at the lower end of the base. In establishing the base line, posts were planted solidly in the ground 20 feet apart, (the length of the measuring rods); on these were nailed cleats of 2 x 4 scantling, two feet in length set to a horizontal line with a levelling instrument. Three rods of well-seasoned pine lumber were made, their ends secured with brass tips planed off perfectly true, and care taken that each rod corresponded exactly in length with a standard furnished from the shops of the Keystone Bridge Company at Pittsburg. The first measurement of the base was 3302.975 feet, second one 3302.935 feet, the average of these was taken as above, their difference being under one-half inch. The angles were then taken, permanent monuments and ranges established. The triangle was a well proportioned one and nearly equilateral, the lengths of the sides being 3302.955 feet, 3579.722 and 3224.306 feet respectively. The angles were deduced by the repetition system, six observations being taken on each point. Levels were transferred to the eastern shore by equal sights of 2,100 feet each on a calm day, and closed within $\frac{1}{100}$ of a foot. Although the river was at a high stage during the month of May, being about 11 feet above low water of 1864, and not to delay operations when it should reach a stage suitable for erecting the piers, soundings were taken at each pier site. These showed the bed of the river to be at some points very uneven, and covered in many places with boulders of all sizes, coarse sand and gravel, and patches of sand varying in depth from six inches in the swifter current to eighteen inches and over as the pier sites approached the Illinois shore and the slack water behind the old Ferry dyke, but underlying all a good solid limestone rock bottom, affording one of the best crossings, as regards foundations, to be found on the Mississippi River, nevertheless demanding other measures to be devised for securing and protecting temporary works during the con-

struction of the piers, than is required where there is a sufficient depth of sand to hold piles.

Location.—The location of the bridge at the upper end of the levee, offers a minimum obstruction to navigation, inasmuch as Keokuk being the head of navigation for the St. Louis steamers, they do not pass above the bridge, having changed their landing place to a better point below; and the up-river steamers having lately adopted the safer method of dropping down stern first through the draw opening, are in much better position to reach their landing place.

The line established was practically the same as that determined from the surveys of 1867. It had then been found necessary to cross the river obliquely, to connect with the tracks of the Des Moines Valley R. R., and avoid using a curve of extremely short radius, also to not occupy any more than was unavoidable of the city levee along Water street. The terminal points are the same, but, in order to comply with the city ordinance, a street 66 feet in width was reserved along the face of the levee, which still further cramped the western approach to the bridge, and rendered necessary the present curve, unavoidable unless the approach could be carried further out into the river and thereby interfere materially with the proposed location of the draw span, and, of still greater importance, encroach too much on the water-way of the main channel, which would have a tendency to increase the velocity of the current, greatest at the Iowa shore, and to render the navigation of the draw spans more difficult to boats, especially those intending to enter the locks now being constructed above the bridge; or else the curve must be extended on to the draw span, which would have been more objectionable for several reasons. The western end of the bridge line commences in the D. V. R. R. tracks, nearly in the centre of Main street and seventy-one feet from the north face of Water street, curves to the right for 597 feet with a radius of 603·80 feet, on a rising grade of 61·25 feet per mile, then runs on a tangent of a nearly due west and east line 2972 feet, to a junction with the tracks of the Toledo, Peoria and Warsaw, and Toledo, Wabash and Western Railways, crossing the current of the river obliquely at an angle of 72° 45′, and descending from the eastern end of the superstructure on a grade of 85 feet per mile for 700 feet, a total length of track of 3569 feet, equal to $\frac{67}{100}$ of a mile.

Description of the Work-Approaches.—The western approach to the bridge consists first of an embankment, protected with a dry slope

wall 384 feet in length, which, for the convenience of the wagon road, slopes back with a macadamized surface from the levee opening and the railway track to the foot of Blondeau street, and extends along the face of Water street 250 feet. The levee opening of 20 feet on the square has two abutments set parallel with Water street, and contain 810½ cubic yards of second class masonry. This opening is crossed with a plate girder for the railroad and a Pratt truss for the wagon road, each truss 38′ 6″ long on the skew. The second portion of the approach is of masonry, forming a cellular curved viaduct with 10 cross walls, being substituted for the embankment at the request of the city authorities; it is 211 feet in length by an average weight of 31½ feet from the rock, with a width of 23 feet over the walls on top; side batir of walls is one in twelve. The superstructure of this is timber; the sidewalks are supported on cast-iron brackets outside the masonry, affording a total width over all of 34 feet, corresponding with the superstructure of the main bridge. Upon this superstructure the character of the whole bridge traffic begins to assume its proper shape, preparatory to crossing the river. The eastern approach is an embankment 750 feet long, 30 feet high at the abutment by 36 feet wide on top, well macadamized and protected with a dry slope wall to the top. Both approaches are fenced, and have gates to close the bridge to travel of all kinds, when the draw span is opened for the passage of boats. Ordinary traffic, it is true, will be impossible during the passage of trains, but as a train moving at the limited rate of six miles per hour would occupy less than seven minutes in crossing, this cannot be considered a serious objection for many years to come.

Piers.—There are fifteen piers of masonry, of which number thirteen stand in the river. In order that the piers should stand parallel with the thread of the current of the river, very careful observations of floats were taken with two instruments, and the time of passage accurately noted. These observations being plotted, the direction of the current in regard to the bridge line was easily deduced and its velocity ascertained. The annexed table, showing the original flowage section and the amount cut off by the bridge, is as follows: water being a medium stage of 4′ 9″ above low water of 1864, the sections commencing at the Iowa shore and measured on the bridge line.

It is believed that the effect of the bridge will not increase the current over one half mile per hour above its present maximum velocity at any time.

Length of Section.	Velocity in feet per second.	Original area.. sq. ft.	Discharge in cubic ft. per second.	Area cut off square feet.	Discharge cut off.	New area sq. ft.
610	4·16	5549	23·085	2319	9647	3230
540	5·00	5517	32·587	198	990	6319
470	4·08	4580	18·686	216	881	4364
580	2·90	5700	16·530	288	835	5412
680	2·00	2789	5·573	1979	3958	810
2820		24135	96·461	5000	16·311	20·135

The current and velocity on the eastern side of the river during the seasons of 1869 and 1870 was very much increased by the unfinished and unconnected state of the work of the canal on the rapids, rendering it still more difficult to do anything during a high stage of water.

Effects of Ice on the Piers.—The piers being set parallel to the thread of the current, make an angle with the bridge axis of 72° 45′, and the superstructure is built on a skew of 17° 15′. The bridge being located at the foot of the rapids will be, in a measure, protected from the ice when breaking up, as, at an ordinary stage of the river, it is very much broken up on the shoals of the rapids. It gorges sometimes on the rapids (but oftener below the city, backing the water up very high), and when the gorge breaks loose, the thrust from the ice on the piers will be very great, but not sufficient to endanger any of the piers. It is very certain that if ice were an unyielding substance, the momentum acquired by a field of ice from the velocity of the current coming off the rapids, would carry away any piers that could be built, but being of a yielding nature, it crushes to atoms as it is ploughed into by the piers' resistance, and the force of impact materially diminishes, and it comes to rest; if other fields still impel it forward, it climbs the nose of the pier and breaks into pieces from its own dead weight. It was ascertained, by experiments at Kansas City Bridge, that sound ice commences to crush under a pressure of 200 lbs. on the square inch, and is crushed to atoms when the pressure is 450 lbs. to the square inch. The hardest blue ice on the St. Lawrence river crushes under 300 lbs. to the square inch. We will, however, in this case, take the crushing pressure at 450 lbs. per square inch, that the ice goes out two feet thick on a stage of water eleven feet above low water of 1864, and that the pier consequently receives

the shock at the change of batir on the nose, being the most unfavorable condition. We have, for the crushing power, the pier being 7′·7″ thick at this point, $\frac{7'\cdot7''\times2'\times144''\times450\text{ lbs.}}{2000\text{ lbs.}} = 496\cdot4$ tons. The momentum tending to overthrow the pier will be equal to this pressure multiplied by the height above the base, or $10'\times496\cdot4$ tons $= 4964$ tons. The moment of stability to resist this overthrow will be the weight of the pier and truss multiplied by the half base length of the pier $= 665$ tons $\times 23'\ 8'' = 15.738$ tons.

To resist the sliding of one course on another, we have the weight of masonry above this point and truss, more than sufficient to prevent sliding, without taking into consideration the resistance due to the adhesion of the cement, or the advantage to be derived from the retreating form of the nose of the pier, which of itself would tend to decrease the force of the blow. We may then safely consider the piers as capable of resisting the impact of the ice at this point. This action of the ice was given due consideration, and a form of pier was chosen adapted to meet the requirements of this case, as well as to offer a minimum obstruction to the water-way of the river. The pier is long and narrow, the angle made by the two faces of the up-stream starling on a horizontal plane is a right angle, with a face batir of six inches in a foot vertical, giving the cutting edge of the pier a slope of about eight and one half inches in one foot rise for a height of ten feet above navigable low water, the remaining ten feet of the starling has a face batir of three inches, and a nose batir of nearly four and one quarter inches in a foot rise. The ice-breaker nose is projected with an angle iron $4''\times4''\times\frac{1}{2}''$ extending the whole length of the starling and securely fastened to the masonry. The shoulder of the lower part of the starling is rounded off to a radius of thirty inches. The top of starling is the same elevation as the high water of 1851. The piers have a side batir of one in twenty-four, the down stream end circular with the same batir as the sides.

Dimensions of Piers.—The dimensions of the piers are as follows: The western rest pier is formed on the end of the western masonry approach, is 30′. 8″ × 5′. 6″ at lower end, and 10 feet 6″ at upper end, and is 35½ feet high.

Pivot-pier and Protections.—Pivot-pier is circular with projections to receive the ends of the foundation cribbing between the upper and the lower draw rests, and the ends of the floats forming the protection to the draw span is 32 feet in diameter under the coping (with cross walls supporting a centre column 10×10 feet at the base, and 5′ 6″

square at the top, on which the centre of the draw span rests), and is 28 feet high, with a side batir of one in twenty-four. The upper and lower draw rests are of timber, having pockets filled with stone. The upper rest is provided with a cutting nose, sloping one-half to one for the first twelve feet above the foundation, and one-half to one for the remaining fourteen feet, protected with a $4'' \times 4'' \times \frac{1}{2}''$ angle iron as high as on the piers. The lower portion is also sheeted with $\frac{5}{16}''$ boiler plate on the faces and sides. The sides of this rest were $4'' \times 10''$ white oak plank, laid horizontally close together on the up-stream faces, but with open spaces on the sides and ends. The inside cross and longitudinal ties were of 2″ pine plank laid one over each other, and, dapped into the outer courses of oak, were spiked to it with $\frac{3}{4}$ boat spikes, and to each other at the intersections with 6″ cut spike. The whole was sheeted vertically with six-inch white oak, well spiked on with $\frac{3}{4}$ drifted bolts 12″ long. The lower draw rest is built of $4'' \times 12''$ pine plank with open spaces between, but sheeted vertically the same as upper rest. The foundation cribbing is of $12'' \times 12''$ pine, 34 feet wide over all, having pockets 8 ft. $\times$ 8 ft. on the outside only, and filled with stone. As the top of this cribbing is only four feet above low water, it will be under water during the greater portion of the navigable season; a float of white pine is therefore further provided, composed of two courses in height of 12×12 sticks on the outside, united with ties and diagonal bracing, and well sheeted with white oak plank 4″ thick. It is built in three divisions longitudinally; the outside ones being open, afford facilities to remove all débris deposited on the cribbing beneath during high water stages, and the inner one floored over to give more buoyancy; during the time of running ice it is calculated to rest on the cribbing, and its sides will offer a smooth surface. The floats are fitted with three cast-iron rollers at each end working on the projections of the pivot-pier and upper and lower draw rests, with sufficient play so that they can rise and fall freely with the water. East rest pier is 7×29 under coping, and $91 \times 53'.\ 9''$ on the foundation, and 36 feet high. The remaining nine piers are 6×29 feet under coping, and from 49′. 9″ to 52′. 8″ long by 9′. 11″ broad on the foundation, and an average height of 35 feet from the rock to the top of the coping. The eastern abutment has an L wing on the down stream side, and a circular sloping wing on the up stream side, with a radius of 32′ 3″. Total length of abutment 136′ 4″ by 12 feet wide on the foundations, finishes at 5′ 6″ on top, wings and face batir one in twenty-four.

(To be continued.)

PENNSYLVANIA RAILROAD SHOPS AT WEST PHILADELPHIA.

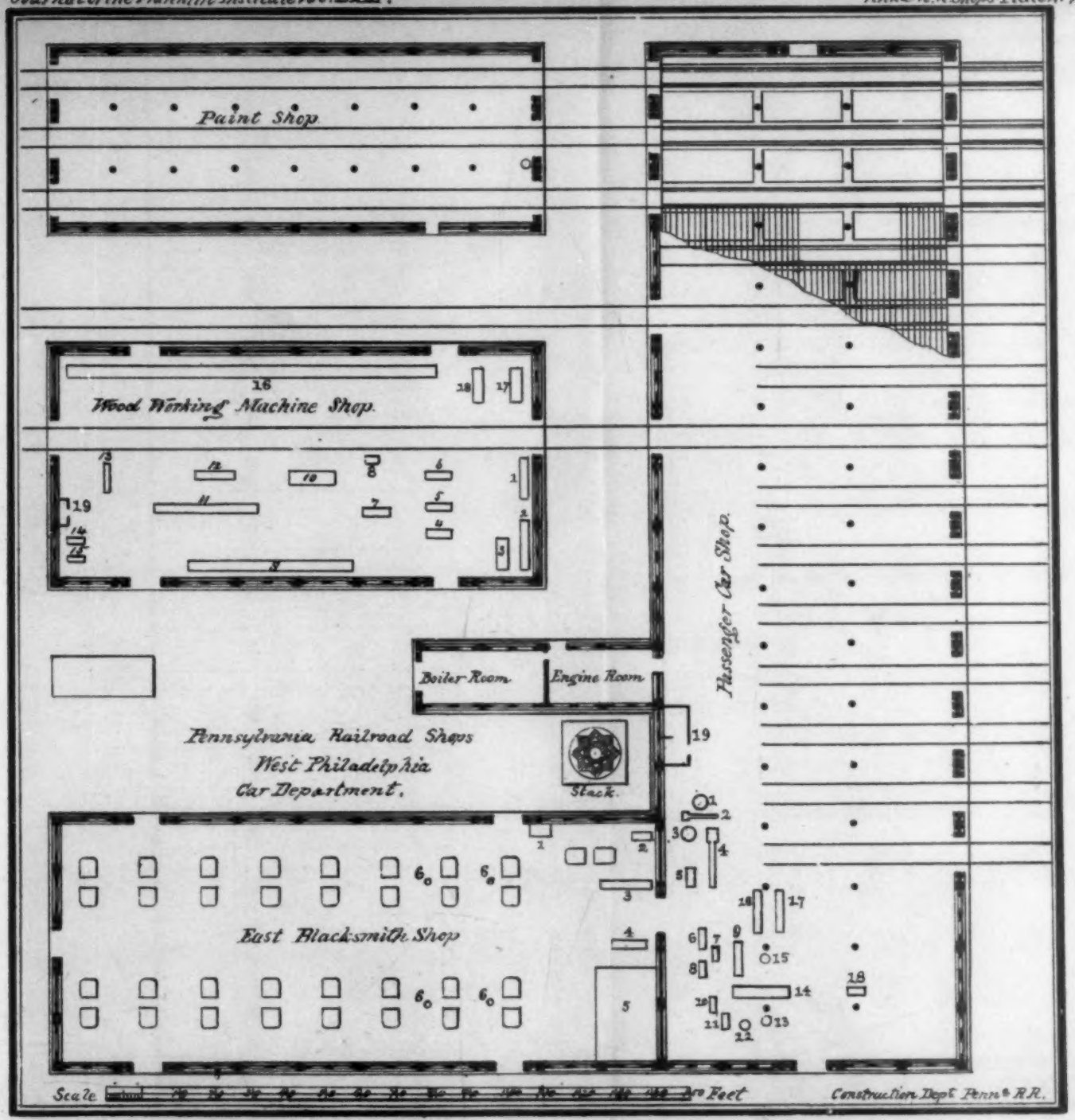
By Joseph M. Wilson, C. E.

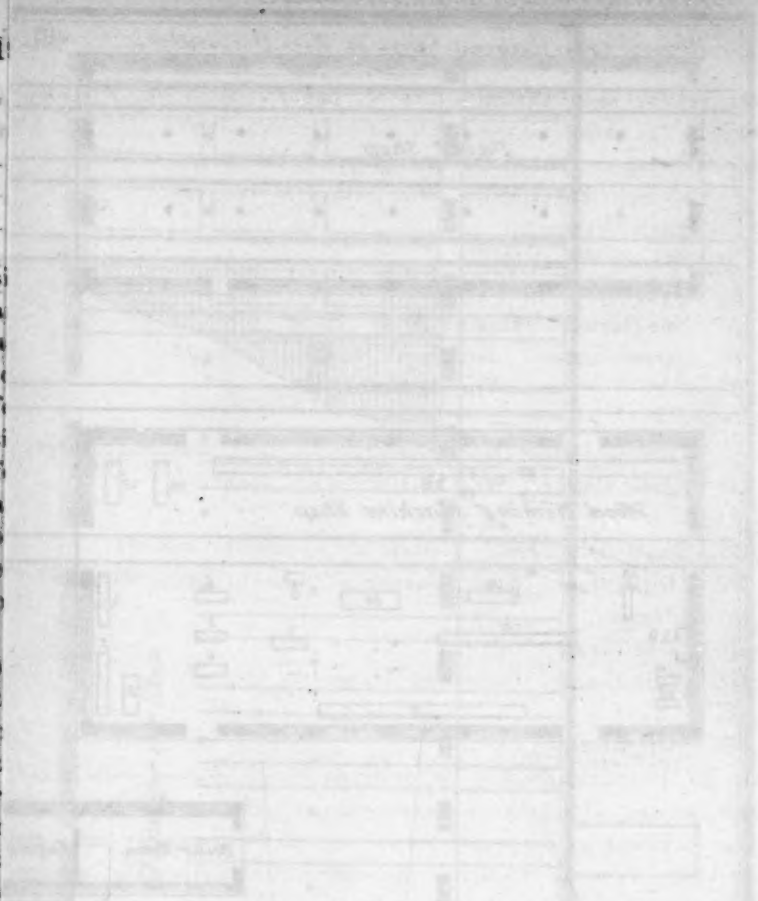
P. A. Engineer Construction Department Pennsylvania Railroad.

(Continued from Vol LXII, page 320.)

Passenger-Car Shop.—This building, marked No. 9 on plate 1, is situated on the opposite side of the transfer pit from the locomotive and machine shop, and enjoys equally with it the advantages of the use of the table. The area of the building is the same as that of the locomotive and machine shop, viz., 280 feet 1½ inches long by 82 feet 8 inches wide, outside dimensions, and the details of construction are the same, except in respect to the roof. It contains tracks for fourteen cars, and although the whole of the area is floored over at present, the foundation walls have been arranged for pits at each of the tracks, so that the building may be readily changed into a locomotive shop whenever an increasing business demands it, and a new passenger-car shop be constructed on another site.

Plate XIV shows a plan of the shop. The roof is divided into three spans by two rows of cast-iron columns, and Plate XV gives a section through the building, showing the construction of the roof. The principals are placed 16 feet 4 inches apart, centre to centre, and the centre span is made much higher than the side spans, the arrangement being easily seen by reference to the plate. By this means a ventilator is formed the whole length of the roof, except on the end panel, the sides of the ventilator having glazed sash, hung to swing on centre and arranged to open and shut in sets, as done in the locomotive and machine shop. In the side spans the principal rafter is 10 by 10 inches section, and the tie beam 10 by 11 inches, and from this tie-beam is suspended the necessary shafting for running the machinery. In the centre span the principal rafters are 7 by 9 inches, and the tie-beam 7 by 12 inches section. The roof is braced longitudinally by trusses, one on each row of columns, extending up to and supporting the centre span of roof. The mode of connecting the side spans with these longitudinal trusses and the columns, and the lateral braces in the centre span, afford ample stiffness to the roof sideways. The purlins are five by eight inches section, placed three feet apart and securely fastened to the principals at intervals, by ⅞-inch bolts. The pitch of side roofs is 22 degrees, and of centre roof 14 degrees from the horizontal. The sheeting is the same as on the other roofs, and the slate is from the Peach Bottom quarries of Pennsylvania, size 10 by 20 inches, laid to weather 8½ inches. The


Paint Shop
Wood Working Machine Shop.
Boiler Room.
Engine Room.
Passenger Car Shop.
Pennsylvania Railroad Shops
West Philadelphia
Car Department.
Stack.
East Blacksmith Shop.
Scale
Feet
Construction Dept. Penna. R.R.



gutters, valleys and eave-pipes are of copper, gauge No. 24, and arranged in the same manner as on the other buildings.

The following is a list of the machinery in this shop:

No. 1. 33-inch Wheel Mill. Wm. Sellers & Co., makers.
" 2. Small Crane.
" 3. 33-inch Wheel Mill. " " "
" 4. Hydraulic Wheel Press. " " "
" 5. Nut Cutter. Made at W. P. Shops.
" 6. Screw Cutter. Bement & Dougherty, makers.
" 7. " " Wm. Sellers & Co., "
" 8. " " " " "
" 9. Turning Lathe, 16 inch swing. A. L. Archambault, maker.
" 10. Screw Cutter. Wm. Sellers & Co., makers.
" 11. " " " " "
" 12. Small Drill Press. Bement & Dougherty, makers.
" 13. Drill Press. Smith Beacock & Tannett, Leeds, England.
" 14. Planer. " " " " "
" 15. Drill Press. " " " " "
" 16. Axle Lathe. Bement & Dougherty, makers.
" 17. " " " "
" 18. Grindstone.

At No. 19 is a small office for the foreman of the shop, with a tool room adjoining. Along the walls are arranged work benches and closets for the workmen, in the same manner as in the locomotive and machine shop. There is an engine connected with this shop for running all the machinery in the car department, and the positions of engine and boiler rooms and stack, are shown in Plate XIV. The boiler is of the ordinary locomotive pattern, built at Altoona shops. The engine is a Corliss, 40 horse power, cylinder 12 inches diameter, three feet stroke. The band wheel is 12 feet diameter and ordinarily runs at 60 revolutions per minute. The stack is exactly the same as the one described previously.

East Blacksmith Shop.—This shop, No. 10 of Plate I, is connected with the passenger-car shop as shown on Plate XIV, and is intended for all blacksmith work required in the car department. It is of the same size as the west blacksmith shop, previously described, and built exactly the same, there being, however, 34 fires in this shop and only 24 in the other. In addition to these it contains

No. 1. Tempering Furnace.
" 2. No. 8 Dimpfel Patent Blower.
" 3. Trip Hammer.

No. 4. Punching Machine. Wm. Sellers & Co.
" 5. Iron Rack, for assorted sizes.
" 6. Small Cranes.

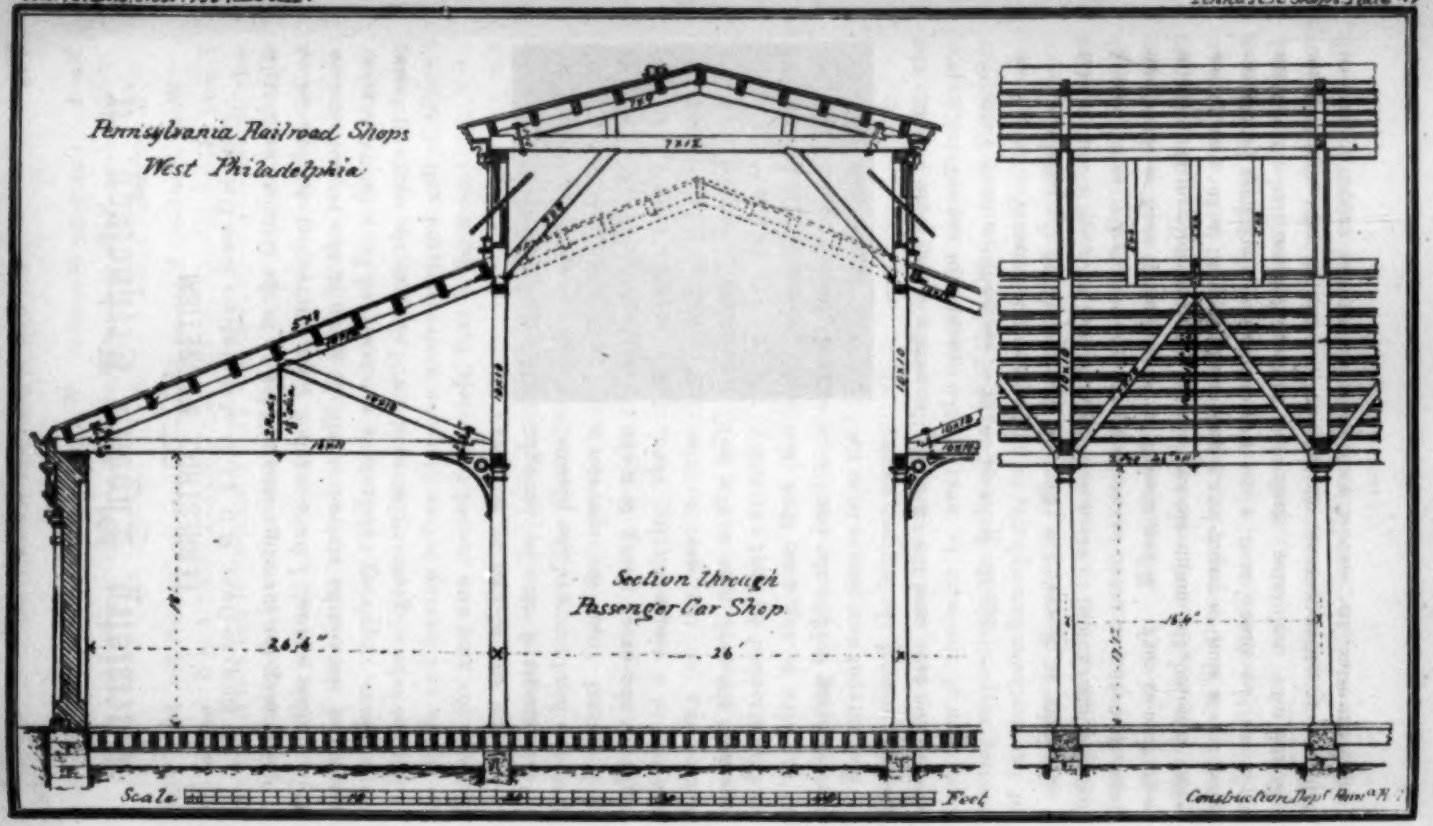
Wood Working Machine Shop.—This is designated No. 12 of Plate I, and covers an area of 132 feet 9 inches by 67 feet 5 inches, outside dimensions of brickwork. It is a building of one story, provided with a single span roof and ventilator, the construction being in every way similar to the other buildings. It has one track lengthwise through the building to facilitate transfer of lumber, and it contains the following wood-working machinery:

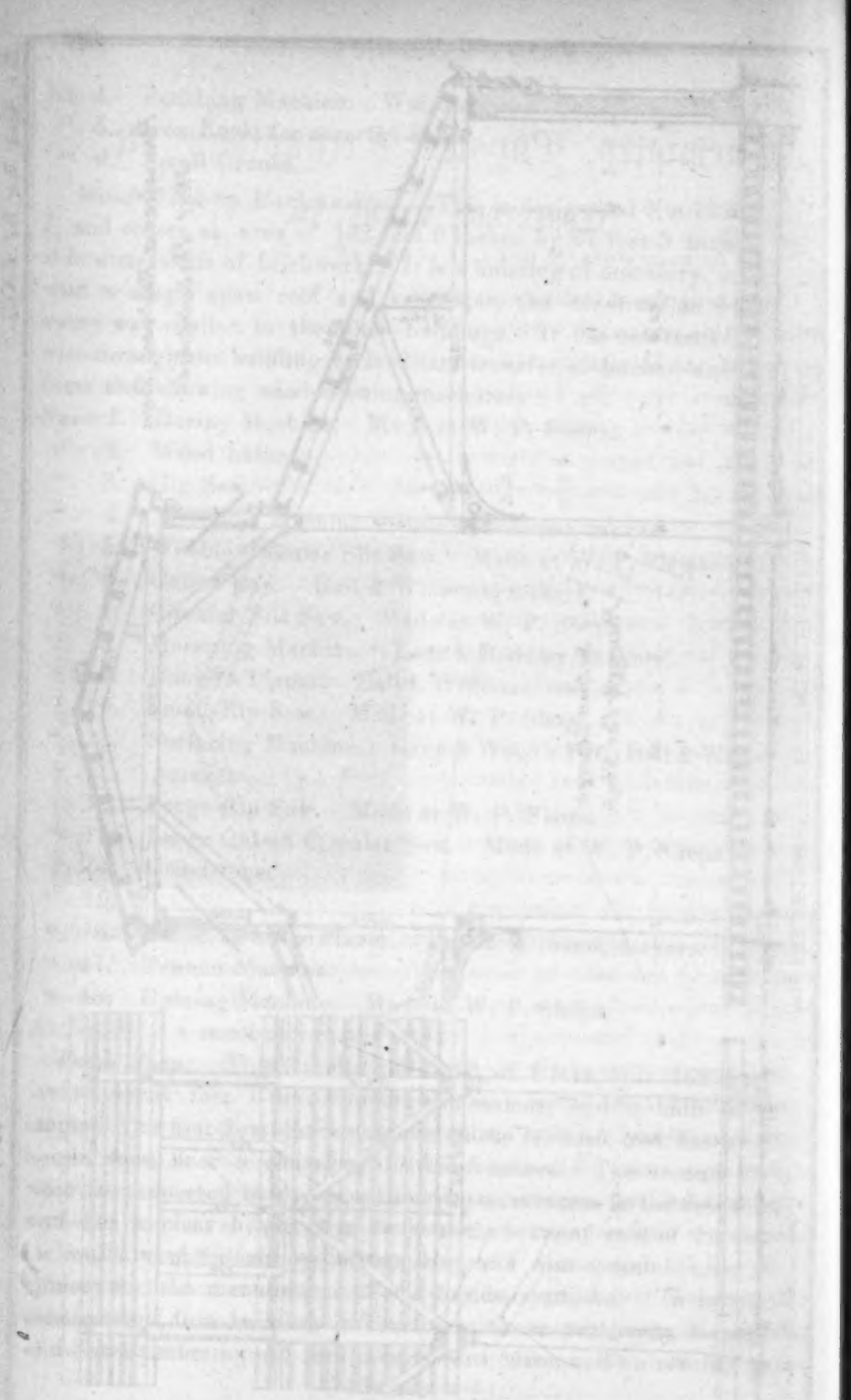
No. 1. Boring Machine. Made at W. P. Shops.
" 2. Wood Lathe. " " "
" 3. Gig Saw. " " "
" 4. Moulding Machine. Ball & Williams, makers.
" 5. Wabble Circular Slit Saw. Made at W. P. Shops.
" 6. Cut-off Saw. Ball & Williams, makers.
" 7. Circular Slit Saw. Made at W. P. Shops.
" 8. Mortising Machine. Lane & Boddley, makers.
" 9. Daniel's Planer. Ball & Williams, makers.
" 10. Small Rip Saw. Made at W. P. Shops.
" 11. Surfacing Machine. Gray & Wood's Pat., Ball & Williams, makers.
" 12. Large Rip Saw. Made at W. P. Shops.
" 13. Large Cut-off Circular Saw. Made at W. P. Shops.
" 14. Grindstone.
" 15. "
" 16. Large Daniel's Planer. Ball & Williams, makers.
" 17. Tennon Machine. " "
" 18. Gaining Machine. Made at W. P. Shops.

At No. 19 is a small tool room.

Paint Shop. This building, No. 13 of Plate I, is 132 feet 9 inches by 51 feet 1 inch outside dimensions, and is built in two stories. The first floor contains three tracks for cars, and has a clear height from floor to ceiling of 17 feet 5 inches. The second floor, which is supported by two rows of cast-iron columns in the first story, and has a clear height from floor to tie beam of roof of 16 feet 6 inches, is used for an upholstery shop, and also contains some machinery for the manufacture of car blinds, seats, &c. In details of construction, this building is similar to those previously described, and has a timber-hipped roof covered with slate, and no ventilator.

(To be continued.)


Pennsylvania Railroad Shops
West Philadelphia
Section through
Passenger Car Shop
26'6"
26'
Scale
Feet
Construction Dept. Penn'a R.R.



Chemistry, Physics, Technology, etc.

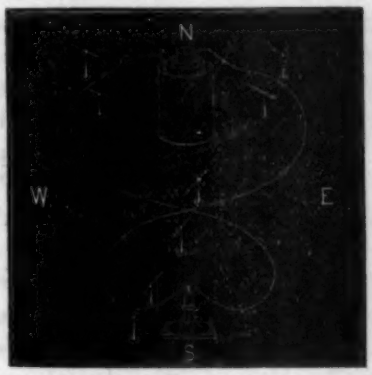
TERRESTRIAL MAGNETISM.

By Richard Owen, M.D. LL.D. of the Indiana State University.

Continuing the investigations alluded to in the October number for 1871 of this journal, I have reached some interesting conclusions. A portion of the results arrived at will be given in this communication, while others, requiring verification, are reserved for a future number.

For the sake of greater clearness, I will suppose the operator facing the north, and having before him one moderate-sized cell of Glove's Battery, the zinc arm turned to the left, that is the west.

Let one end of five or six feet of medium-sized wire be brought from the head screw of the platina, and extend from the operator's right (or the east), rising to make the top of a single circle; then, descending on the west to rise again on the east, pass to the left and be attached by that extremity of the wire to the zinc, thus (the needle being held in the hand):



The current now passes from the platina, around the copper circle, toward the zinc, and the effect on the needle is the same whether the first turn of the wire be next to the operator or the reverse, representing respectively the heliacal curve of the ecliptic, as in the winter of our northern hemisphere, or again as in our summer.

In order to observe the effect of this current on the needle, I have found it convenient to use a delicate compass, with agate centre, lifted from its case and made to oscillate on a sewing needle thrust through a portion of cork. When needed for experiments such as those hereafter detailed, the magnetic needle and sewing needle on the cork are placed in a shallow paper box which can be carried in the vest pocket.

It will be found that when the current of electricity (whether a vibratory or undulatory molecular motion, transmitted in vortical, heliacal or other curves, matters not for the present object) passes along the wire, the needle *outside* and near the copper circle will

stand in the natural position of all magnets which are fully suspended in the plane of the magnetic meridian, but *inside* the circle the poles will be reversed. When the needle is *above* the wire, on the experimenter's right, the north end of the needle will be deflected west; when it is *below* the wire the north end of the needle turns to the east. Just the reverse is the case when the needle is applied above or below the wire on the left, or west, or zinc end of the same.

All the above results accord, I believe, with the statements of the best writers on the subject from the days of Oersted to the present time, and they are here merely reviewed to make more apparent the conclusion to which we seem forced, namely, that if currents of electricity, in or about the earth's crust, are the cause of the magnetic needle (when free from all local disturbance) settling in the magnetic meridian with its north end nearly to the north, then those currents, if they encircle the earth from east to west, must be *beneath* the magnetic needle, not in the air above the needle. Consequently the vibrations must be comparatively deep in the earth's crust, being greater in power as we go deeper. This seems to be the conclusion arrived at by Mr. Robert Fox, after experimenting on electrical currents in metallic veins, as given p. 98, Part IV, of Electro-Magetism, in the "Library of Useful Knowledge."

Horizontal Induction.

There is, however, another mode of accounting for our horizontal needles settling north and south, even supposing those currents proved, and granting further that the magnetism exhibited in the earth may result from these currents: that other mode is by *induction*.

Every iron rail laid on a north and south railroad, so far as I have been able to examine, is a perfect magnet, the end stretching to the north attracting the south end of the needle for about half of its distance; while the end stretching south attracts the north end of the magnetic needle for about the other half of the entire length of the rail. If native lodestone or magnetic iron ore is rendered so by the earth's inductive power, just as these rails have been rendered magnetic by induction, then—if the first artificial magnets were made to acquire their directive tendency by drawing first one pole of the lodestone from centre to end of the steel bar or needle, afterwards the other lodestone pole being rubbed from centre to the opposite end (and successive artificial magnets have been manufactured from these first by drawing them from centre to each end at a given angle)—we are,

perhaps, justified in saying that almost all artificial magnets (whether as mariner's compass or other magnetic needles) have been made magnetic indirectly from the inductive action of the earth. Some, it is true, have been and can be made magnetic by hammering, or by electric shocks, &c.; others, also, by the violet rays of the sun's beam; but that would not invalidate the truth, as above stated, that almost all artificial magnets are made so by induction, not that form which acts feebly at a distance, but rather the more powerful by actual contact of other magnets, and indirectly of the earth.

As a transition from this mode of horizontal induction to another phase, vertical induction, I may mention that for some distance *near the middle* of each north and south rail of the so-called T railroad iron, instead of all parts of the T rail, whether tested by the needle above or below, attracting either the south or the north end of the needle, it will be found that the lower flange, whether tried on the east or west side, will attract the south end of the needle, while the upper flange attracts the north end of the needle.

This brings us to

Vertical Induction,

Or, perhaps, we might say induction separating the two magnetisms in a plane nearly at right angles to the plane formed by the supposed extension of the upper surface of a flat dipping needle.

All iron bodies, whether cast, hammered or rolled, which have for a longer or shorter period (sometimes a day or less sufficing) been fastened in a somewhat vertical position, or even left loose habitually in an upright position, become magnets, and most of them remain so permanently.

It is usually stated in works on this subject that pokers, shovels and the like standing for a time in a vertical position become magnetic. If the poker is of soft iron, I find the magnetism can be reversed in a moment by reversing the poker; but it is not so with many articles I have tried, even when made of sheet iron.

Thus, after testing several hundred articles of iron, that had been some time in permanent positions relatively to the earth, I found them invariably magnets, attracting the south end of the needle at the lower side, and the north end of the needle at the upper side. This polarity was not reversed when a sheet-iron vessel was turned bottom up for 12 hours. Thus the lower part of a cast-iron or sheet-iron stove, sheet iron bucket, tin pan (*i. e.* iron tinned), or iron fence, also the

lower straps bracing the trucks of a freight car, or the lower edges of the straps on the corners as well as the lower parts of all locks and hinges fastened on doors, attract the south end of the needle, while the upper parts of the same, the upper rail of the fence (when connected with the lower either by cast or wrought iron), or the upper part of a bucket or even of a shallow saucepan, will attract the north end of the needle.

The two iron straps with which the trucks of cars are braced, are united by rivets at each end, while above and below the axle they are more than a foot apart. Although the upper strap along most of its length attracts the north end of the needle, and the lower strap the south end, as just stated, yet where they come together, if the car has been standing or running some time in a given direction, the junction and rivet next the north end of the railroad will attract the south end of the needle, while the junction and rivet pointing to the south end of the road will attract the north end of the needle.

The old cast trucks or car wheels (united by their axles) which have been for some time in one position, near the machine shops, standing on north or south rails, are found also to exhibit the effects of both vertical and horizontal induction, for every wheel at its upper part of the rim attracts the north end of the needle, while at its bottom it attracts the south end; again half way from bottom to top on the part of the rim facing the north it attracts the south end of the needle, while on the rim facing the south we find magnetism attracting the north end of the needle. I use the term vertical induction, because it seems evident that all bodies occupying a nearly vertical position have the opposite magnetism of that evinced by our northern hemisphere, attracted nearest to our part of the earth's crust, while the magnetism, similar to that of our earth here, is repelled to the upper part of the iron article, whatever it may be and of whatever length. The division between the two magnetisms seems to vary; but in a nearly cubical sheet-iron vessel used for chemical purposes in the laboratory of the Indiana State University, I marked with chalk the turning point of the needle on the four upright sides, and connected these by lines. These lines were found to occupy a plane nearly at right angles to the plane of the upper surface of the dipping needle at this place.

Another result, which might have been expected from the analogy between the vessels thus found magnetic and any artificial magnet, deserves a brief notice.

A new French coffee-pot, capable of being separated a little above its middle so that the part containing the strainer becomes a distinct upper vessel, was found when entire to attract the south end of the needle when presented near the bottom of the vessel, and the north end, when presented anywhere from below the middle to the summit. When, however, the coffee-pot was separated, so as to make two vessels, *each* had its distinctive polarity, just as in breaking a magnet in two and obtaining two magnets.

It seems quite possible that considerable influence may be produced in various ways by this disturbance of the magnetic equilibrium, existing, as it appeared to do, in all the vessels ordinarily used for culinary and other domestic purposes; but for the present it is perhaps sufficient to call attention to this effect of induction operating so very extensively, the verification of which can be so readily and interestingly accomplished by any one having a delicate magnetic needle.

As a horizontal needle weighted on its south end for the northern hemisphere, and on the north end for the southern hemisphere, in order to overcome the dip, will continue to point north and south in either hemisphere, so a north and south rail, taken up after lying some time on the earth in either hemisphere and swung freely, would set itself, as it lay in the ground, north and south. But in the case of vertical induction, as the dipping needle is horizontal near the equator (say at St. Thomas' Island, close to west coast of Africa) while at the magnetic north pole the *north* end would turn down and point to the centre of the earth, and at the magnetic south pole the dipping needle would point with its *south* end to the centre of the earth, the phenomena of vertical induction would seem to be necessarily reversed in these two hemispheres, except near the equator, where vertical induc duction would probably be lost or merged in horizontal induction.

It would be highly interesting if some scientific men would examine, at the Cape of Good Hope, or in Australia, or in South America, and give us the results of their examinations. Also if some, stationed near the magnetic equator, would apply the tests above and give results.

To prevent misapprehension, it may be proper to remark that, in using the term magnetism as applied to the power communicated to iron vessels by the earth's induction, it is not meant to imply that all these vessels, &c., can be made to exhibit the power of attracting iron filings (although some pointed articles do so), but rather that they all

exhibit polarity, whereas iron in which, from its constant change of position no such induction has taken place, would attract either end of the needle with equal readiness.

I may also add that the converse of separating a tinned vessel, as a coffee-pot, into two parts and obtaining two magnets, holds good; for if we take two tin cups or two cans of equal size, and having each polarity, and place one on the other, we shall have the lower vessel attract the south pole of the needle, the upper vessel the north pole of the needle, as if they constituted but one magnet.

Magnetic Springs.

As the waters (in which steel instruments or tools, such as axes, &c., when left some hours became magnetic) have latterly been exciting interest in a medical point of view, in consequence of their reported therapeutic power in various diseases, I concluded to make some experiments, endeavoring to ascertain the manner in which the waters become magnetic.

Pouring half a gallon of rain water into a small tub, I placed two steel magnets (half-inch bars a foot long) parallel to each other in the plane of the magnetic meridian, in the water six inches apart and having opposite poles facing each other. I then dropped a tenpenny nail between them in an east and west line, near the north side of the tub. After five hours the tenpenny nail, when taken out, lifted a tack of the size known as 8 oz. tacks. Taking the magnets out, I then dropped another tenpenny nail into the water, which had thus been impregnated with magnetism; and in twelve hours found this nail would, when taken out and dried, lift an 8 oz. tack also.

Time has not permitted, as yet, any variation in this latter experiment, but should the subsequent results either confirm or contradict those obtained above, I shall communicate them.

MONTHLY RAINFALL AT SAN FRANCISCO.

By Pliny Earle Chase, Professor of Physics in Haverford College.

Mr. Thomas Tennent has published a chart, compiled from his own observations, of the monthly amounts of rain in San Francisco for twenty-two years, from July 1st, 1849, to July 1st, 1871. I have grouped the amounts in seven short periods, and computed the normal ordinates (N) for the several curves, which are given, together with the observed amounts (R), in the following table:

SAN FRANCISCO RAINFALL.

	1849—52		1852—55		1855—58		1858—62	
	R.	N.	R.	N.	R.	N.	R.	N.
July	.....	3	.....	3	·02	2	·26	6
August	.....	9	.'5	6	·05	3	·18	4
September	1·03	41	·61	23	·07	16	·05	19
October	3·35	111	3·33	65	1.38	57	3·70	64
November	12·03	196	7 93	116	6 47	136	12·65	142
December	14.35	228	16·33	176	13·65	219	23·41	220
January	9·64	191	11·47	103	16·21	249	29·75	248
February	2·45	155	14 23	194	10 92	217	19·17	208
March	13·15	136	13 01	185	8 77	156	13·29	140
April	1·95	90	13·49	142	4·49	92	4 65	83
May	·99	34	2 28	74	1·12	40	6·15	46
June	.....	8	.08	21	·20	12	·22	21

	1862—65		1865—68		1868—71		1849—71	
	R.	N.	R.	N.	R.	N.	R.	N.
July	.....	5	.....	2	.....	1	·28	3
August	·21	3	.....	1	.....	3	·49	4
September	·04	20	·39	11	·15	12	2·34	20
October	·53	84	·46	58	1·44	44	14·19	67
November	9·38	187	10·95	155	2·80	115	62·21	149
December	13·06	252	26·43	249	12 03	206	119·26	221
January	10·60	229	25·54	267	13·31	257	116·52	235
February	4·53	161	15·45	210	12·44	235	79·19	200
March	4·32	113	10·92	135	6·43	171	69·89	148
April	4·13	81	4·79	73	5·65	101	39·14	94
May	1·64	48	1·49	31	·49	44	14·16	45
June	.....	17	·27	9	·02	11	·79	15

There is so much similarity between the different curves, their general character is so much like that of the Lisbon curves, and they accord so nearly with the annual temperature curve, that they may reasonably be regarded as typical, and the daily records may probably furnish materials for more minute and detailed profitable investigation.

Among the deductions in my paper on the "Tidal rainfall of Philadelphia," (*Proc. Amer. Phil. Soc. x.*, 530), were the two following:

1. "The tidal rainfall, like the ocean tides, is affected by 'establishments,' which depend upon ocean currents, mountain ranges, prevailing winds and other climatic influences.

2. "It is also, like the ocean tides, more marked in low, than in high latitudes."

These inferences are strikingly corroborated by the Lisbon records, and I look confidently for equally striking additional confirmation from observations on our Pacific coast. Moreover, I think that my previous discussions, combined with generalizations from the meteorological reports of the Signal Service Bureau, and with well known tidal laws, are sufficient to justify the following predictions:

1. The tidal rainfall will generally be found more strongly marked on the western shores of the several continents, than in the same latitudes on the eastern shores.

2. When the rainfalls at any given station are grouped both in accordance with the age of the moon and the direction of the wind which brings the rain, opposition of winds will be found to affect the tidal curves similarly to opposition of direction from large bodies of water.

3. A certain degree of apparent opposition will be found to exist between the lunar influence upon the upper and lower cloud strata, dependent upon the normal difference of position in the tidal crests of deep and shallow fluid envelopes.

4. The satisfactory determination of the lunar influence upon atmospheric currents is practicable, although vastly more laborious than the determination of the laws of tidal rainfall. Glaisher has already shown that there is such an influence, but there have been no published discussions of its amount or general character.

THE RUMFORD MEDALS.

At the last annual meeting of the American Academy of Arts and Sciences, held in Boston, May 30th, 1871, the Rumford premium was awarded to Mr. Joseph Harrison, Jr., of Philadelphia, "*for his method of constructing steam boilers, by which great safety has been secured.*" According to the directions of Count Rumford this premium was given in two medals—one of gold and one of silver—together of the intrinsic value of three hundred dollars, and at the last monthly meeting of the Academy, a formal presentation of the medals was made.

The medals presented to Mr. Harrison are alike except in the kind of metal of which they are made. On the obverse is a bass-relief portrait of the count, surrounded by his name and the dates of his birth and death (1755 and 1814). On the reverse is the following inscription :—

"*Rumford Medal for discoveries in Light or Heat. Awarded by the American Academy of Arts and Sciences, to Joseph Harrison, Jr., for his method of constructing steam boilers, by which great safety has been secured. May* 30, 1871."

The grounds on which the medal has been awarded to Mr. Harrison are fully set forth in the following statement of the Rumford commit-

tee of the Academy, which was adopted at a full meeting of the committee held December 23, 1871, and was read to the Academy, Tuesday evening, by the chairman of the committee, Professor Josiah P. Cooke, Jr.:

The "Harrison boiler" consists of a number of hollow cast-iron spheres, about eight inches in external diameter and one quarter of an inch thick. These spheres are cast in groups of two or four, the spheres of each group being arranged in straight lines and connected with each other by curved necks about three and one quarter inches in diameter. Moreover, each sphere has two half necks which make openings at right angles to the necks previously mentioned. The open necks are rabbeted so that any number of the groups of spheres (units as they are called) may be united to each other, and the system thus built up is held together by wrought-iron tie-bolts, which pass through each line of spheres in the direction of the half or jointed necks, connecting at each end with caps that close the external orifices of the end spheres on each line. The castings are made with such uniformity, and the necks turned so as to fit each other with such accuracy, that when rabbeted ends are adjusted and drawn together by the screw and nut at the end of each bolt, a perfectly steam and water-tight joint is secured without the intervention of cement or packing. A system of spheres thus united, six wide and twelve or thirteen long, forms what is called a section, and a boiler consists of several of these sections all discharging steam into the same pipe. In setting the boiler the sections are placed on edge, side by side, so that the lines of bolts make an angle of about forty degrees with the furnace grate.

The security of the "Harrison boiler" depends upon the following features in its mode of construction. In the first place the spherical form adopted for the units of the boiler greatly economizes the tensile strength of the iron, and it has been estimated that with a metal having a tensile strength of three and one-half tons to the square inch, the bursting strength of the units would be nearly three-fourths of a ton per square inch. The strength of a boiler consisting of such units will of course be no greater than that of the weakest sphere of the structure; but as all the sections are tested at the manufactory by hydrostatic pressure as high as three hundred pounds to the square inch, a defective unit is discovered before the boiler is delivered to purchasers.

It is not maintained, however, that the units of the "Harrison

boiler" cannot be burst under excessive pressure, for, as experience has shown, it is impossible to make a vessel—at least one of any practical value as a steam generator—which cannot be burst. It is merely a question how high a pressure it can stand before yielding. But the evidence before the Rumford committee has sustained the opinion that in case of such an accident to the "Harrison boiler" a violent, destructive explosion is almost impossible; and this brings us to the consideration of the second feature on which the security of this boiler depends.

In an ordinary plate-iron boiler the yielding at any point almost inevitably involves the rending and complete destruction of the whole structure. A tear started at a defective rivet or on a line of corrosion will instantly lay open the whole vessel, when the expanding steam scatters the contents in all directions and hurls the fragments with a force that no ordinary construction of buildings or ships can withstand. The recent experiments of Mr. Stevens, of Hoboken, as described in a report to the Secretary of the Navy by three of the chief engineers in the naval service, show very conclusively that this tearing apart of the boiler plates under pressure is the simple cause of the destructive explosions of plate-iron boilers, and, to use the words of the report, "that in accounting for either the fact of an explosion or for its destructive effects there is no necessity for hypotheses of low water, enormous pressure, instantaneous generation of immense quantities of steam, superheated steam, the formation of hypothetical gases, the development of electricity, etc. The most frightful catastrophe can be produced by simply gradually accumulating the pressure of the saturated steam to a strain at which the strength of the boiler yields, nor need that pressure be much above what is ordinarily employed with boilers of this type." In one experiment the boiler exploded with most destructive violence in less than a quarter of an hour after the pressure had passed the inspector's limit.

Such a sudden tearing open of the whole vessel has never taken place and does not seem to be possible with the "Harrison boiler." Under an excessive pressure, the weakest unit in the system may yield and injury may be caused by the sudden discharge of water or of steam, but the injury to the boiler must be, to a great extent, local, probably extending only to the breaking of a single unit, and involving at the most a rapid but still regulated emptying of its contents. The parts being wholly independent, there is no tendency in a rupture to extend from one unit to its neighbors, and, moreover, as a general

rule, long before the bursting point is reached, a third feature of the boiler comes into play which, perhaps, more than either of the two others, protects it from destructive explosions. The units of the boiler not being cemented together, the least yielding of the bolts opens every joint and makes each of them a safety valve. That this is the normal action of the boiler under excessive pressure has been abundantly established, not only by the experiments made by Mr. Harrison before a committee of the Franklin Institute, but also by the experience of a member of our own committee.

The Rumford committee were satisfied by the evidence herein stated that the "Harrison boiler" is not liable to those violent destructive explosions referred to above, and to which the ordinary plate-iron boilers, however carefully or strongly made, must be always more or less exposed. Considering further the economical advantages to be gained from high pressure steam, and the paramount importance of such security as Mr. Harrison has attained in the use of this powerful agent, they felt themselves justified in making the recommendation on which the Academy acted in awarding to him the Rumford medal. It must be noticed, however, that the award has been made for a "mode of constructing steam boilers by which *greater safety is secured*," and that the safety of the boiler is the only point on which the committee based their recommendation. They did not feel themselves called upon to weigh carefully the relative merits of the "Harrison boiler" when compared in *other* respects with the many forms of steam boilers now in the market. They considered that its already extended and rapidly increasing use was sufficient evidence that the "Harrison boiler" was an efficient and economical steam generator. More than this they did not require to be proved; for whatever might be the defects of the boiler—and some doubtless there are—the committee considered that Mr. Harrison had made an important advance in the application of steam by demonstrating experimentally the principles on which a safe steam boiler can be made, and working them out to a practical result. These principles being established, we may hope that the alleged defects in the present construction may be hereafter remedied.

It remains only to be considered how far the principles or features of construction to which we have referred are original with Mr. Harrison. At least twenty-five years ago Dr. Ernst Alban, a distinguished German engineer, clearly recognizing the impossibility of securing safety in a steam boiler by strength of materials alone, ad-

vanced the important opinion that the only sure method of avoiding danger is "so to construct the boiler that its explosions may not be dangerous," and in a valuable work, originally published in Germany, but of which an English translation, published in 1848, was alone before the committee, a mode of constructing steam boilers is described, in which this principle is skilfully applied. Mr. Harrison has adopted the principle of Dr. Alban, and in a pamphlet on the steam boiler published in Philadelphia in 1867 he prints the opinion of Dr. Alban, quoted above, at the head of his essay, but his method of embodying this principle is as dissimilar as possible. Moreover, he has carried out the principle more fully than Alban himself. The German boiler, like the American, is made in sections, so that the bursting of one would bring no destructive consequences upon the general body of the boiler; but it is merely a modification of the well-known tubular boiler, and does not combine the advantages which Harrison obtains from the spherical form of his units and the mode by which they are bolted together without rivets or cement.

But the merit of Mr. Harrison and his claim to the Rumford medal consists fully as much in the skill with which he has overcome the difficulties in the details of the construction of his boiler as in the ingenuity of the original design. The boiler is not an ideal conception, but an accomplished result, of which the industry of the country is enjoying the benefit. By Mr. Harrison's labors, high pressure steam has been brought more under control, and human life has been rendered more secure. The Rumford committee believe that in awarding the Rumford medal to Mr. Harrison, the Academy are not only faithfully carrying out the expressed wishes of their benefactor, but also that Mr. Harrison's invention is one which Count Rumford would have especially delighted to honor.

Mr. Harrison, in consequence of illness, not being able to be present at the meeting, the medals were delivered, at his request, to Mr. John A. Coleman, who read to the Academy the following letter of acknowledgment:

To the President and Members of the American Academy of Arts and Sciences:

Mr. President and Gentlemen:—In receiving the Rumford medals awarded to me in so flattering a manner by the American Academy of Arts and Sciences, I fear I cannot express in suitable terms my appreciation of this most distinguished honor. I can therefore only

say that I do esteem this compliment very highly indeed. To my mind, there is nothing within the limits of science at this present time that is of more importance than the "application of heat" to the safe generation of steam, and to have won a recognized distinction in such a field, and to have been deemed worthy of the reward that I have now received, fully repays me for many years of anxious and often discouraging effort. In what I have done I claim but little merit beyond calling attention for the last twelve years to the great importance of the subject, and in having in some degree demonstrated the fact that a steam-generator can be made secure from destructive explosion. I think that this idea has now taken such firm hold upon the public mind, both in this country and in Europe, that it may be fairly inferred that in the future the use of steam under pressure will not be attended with the disastrous results that are recorded in the past. In regretting my inability to be present at your meeting on January the 9th, so as to receive the medals in person, I most sincerely thank you, Mr. President and members of the American Academy of Arts and Sciences, for this very high mark of approval.

JOSEPH HARRISON, JR.

Philadelphia, January 6th, 1871.

The medals presented to Mr. Harrison are the sixth award of the Rumford premium made by the American Academy. The other awards have been made as follows:

In 1839, to Dr. Robert Hare, of Philadelphia, for his invention of the compound blow-pipe, and his improvements in galvanic apparatus.

In 1862, to Mr. John B. Ericsson, of New York, for his caloric engine.

In 1865, to Professor Daniel Treadwell, of Cambridge, for his improvements in the management of heat.

In 1867, to Mr. Alvan Clark, of Cambridge, for his improvements in the manufacture of refracting telescopes, as exhibited in his method of local correction.

In 1870, to Mr. George H. Corliss, of Providence, for improvements in the steam engine.

It was directed by Count Rumford that the premium should be given "to the author of the most important discovery or useful improvement, which shall be made and published by printing or in any way made known to the publick, in any part of the Continent of America or in any of the American Islands, during the preceding two years, on Heat or on Light; the preference always being given to

such discoveries as shall, in the opinion of the Academy, tend most to promote the good of mankind." In Count Rumford's original letter of donation, dated London, July 12th, 1796, beside the above, several other directions are given, with some of which the Academy found it impracticable, or at least very inexpedient to comply literally, and for this reason the premium was not awarded during a long series of years. The Academy is now acting under a decree of the Supreme Judicial Court of the Commonwealth of Massachusetts, especially authorized by an Act of the Legislature of the State, approved by the Governor March 16th, 1831. This decree enables them to award the premium at any annual meeting, and relieves them from the necessity of limiting its application to discoveries or improvements made during the two years immediately preceding the award. All interested in the subject will find a full statement of the facts in the Life of Count Rumford, by the Rev. George E. Ellis, D. D., of Boston, recently published for the Academy (in connection with an edition of Rumford's complete works) by Claxton, Remsen & Haffelfinger, 319 and 321 Market St., Philadelphia.

A committee, consisting of seven fellows, called the Rumford Committee, is annually appointed by the Academy, and it is their duty to investigate all claims for the Rumford premium. The premium is awarded only on the recommendation of this Committee, and at the annual meeting of the Academy held on the fourth Tuesday in May. The Rumford fund would enable the Academy to give the medals every year, but the premium can be awarded only for a new discovery in light or heat, or for a substantial improvement in the application of these agents to the arts of life, whose usefulness has been tested by experience.

All communications on the subject of the Rumford premium should be addressed to the Chairman of the Rumford Committee, American Academy of Arts and Sciences, Boston, Mass.

LECTURES ON VENTILATION.

Delivered before the Franklin Institute.

By L. W. Leeds, Esq.

(Continued from Vol. LIV, page 120.)

I have hung on the sides of the room—one on the right and the other on the left—the two lists of tables of the analysis of the air I copied from a report to Congress on the ventilation of the capitol,

made by Professor Henry, Thomas U. Walter, and Dr. Wetherill. (The same tables used last year—see page 17.)

The one on your right hand shows the amount of carbonic acid in the open air; and the one on the left, the amount found in buildings.

By an examination of these you will readily see that all external air, such as the sheep, and calves, and colts have to breathe, is uniformly very pure, while that in houses, such as we and our children have to breathe, is very different.

You see, here, in our scientific lecture-rooms, school-houses, bedrooms, we have 50, 60, and even 72 parts of carbonic acid in 10,000.

It is that excess of carbonic acid—over 5 parts in 10,000—that represents the foul poisonous condition of the air of our houses, which is killing so many of the people of this country.

I consider these tables valuable, because they are nearly all the analyses of air that have ever been made. Comparatively speaking, we do not know anything about that subject as we ought to know.

Let me ask you if it is not passing strange that a great and intelligent nation, like the United States, should so utterly neglect this important subject? A nation that can raise such vast armies, and can raise millions, hundreds and thousands of millions of dollars for destroying each other in time of war, yet scarcely one dollar for analyzing the air and endeavoring to control it and prevent the destruction of human life by that fearful poison—foul air—that killed more persons in the United States last year (a year of profound peace) than were killed on the Union side by sickness, and by the enemy, during the entire late war.

If there is a case of poisoning by arsenic or strychnine, the whole city is thrown into a state of feverish excitement, and if not suspected until after the body is buried, it is exhumed and the most skilful chemists work faithfully over it to ascertain, if possible, some trace of the poison; and yet some 3,000 children were poisoned to death in this city by foul air last year, and can you produce one solitary record of the analysis of the air of the room in which they were thus killed?

Is there one of your medical colleges, the boast and pride of this city, that teaches its students, by careful analysis of the air, readily to detect and how to remedy those impurities which physicians must constantly meet with in the sick-room? Let us hope that the day is not far distant when the people will be aroused from their guilty apathy and indifference upon this subject.

We now propose examining the ventilation and heating, as it is applied in various public and private buildings with which you are familiar.

It is not a pleasant task to examine and find fault with the new and splendid buildings that have just been completed, at such great cost, and which are looked upon by their owners and most casual observers as models of beauty and perfection. But, are not these buildings the true index of the general public information upon these subjects? And is it not, therefore, best for all of us that we should give them the most critical examination, and if they are merely showy tombs, as it were, and entirely devoid of the proper supply of that life-giving element, *pure air*, to acknowledge the truth promptly and then set ourselves to work energetically to endeavor to learn the best way of improving these, and avoiding such mistakes in all new ones?

There is no building in the world, perhaps, upon which there is such a decided diversity of opinion among scientific men as to the perfection of its ventilation as there is respecting the Capitol at Washington. I have devoted much time for many years past to studying its peculiarities, and I think if the mere question of a constant supply of air to the main rooms was the only one, it can readily be proven to be well ventilated, and yet it would be very difficult to get any considerable number of the owners who are obliged to occupy the building for a large portion of the year, to consent to any such statement.

The universal dissatisfaction is probably owing as much to the quality of the air supplied, and the manner of heating it, as to the quantity.

I consider this a good example of the ill effects of that detestable system that we as a nation have fallen into, of attempting to warm our buildings by over-heating, and thus ruining all the air used for breathing.

The total absence of any direct radiation is a marked feature, for there is not only the entire absence of any artificial radiation from exposed steam pipes, etc., but there is the additional absence of radiation from the great natural source of all heat, the sun.

The direct rays of the sun I believe to be not only the most magnificent warming power, but also the greatest disinfecting and purifying power we have, and they are of the utmost value for the vigorous development and exercise of all our physical and mental faculties.

It appears to have been originally designed to exclude the main

halls as much as possible from all external influences, and to have all the currents, the heating and the lighting, under perfect artificial control.

But if the whole nation could be taught the valuable lesson of the great folly of attempting to produce artificial light, artificial heat, and artificially mixed air, that shall be equal to that which our Creator has provided for us, that knowledge would be cheaply bought at the great price paid for these buildings.

I tried a large number of experiments during the winter of '67 and '68 to ascertain the direction of the prevailing currents through the Hall of Representatives and the relative temperatures in all parts of the building. I was rather surprised to find them so distinct and well defined, and also that they were so free from disturbance by the changes in the direction and force of the external currents.

The heat all entering the hall, or passing under it on the west side, gave an additional temperature of 4 or 5°, which was sufficient to cause an ascending current at that end, which produced a corresponding descending current at the other end. A very striking feature was the effect of the exposed copper roof in cooling the foul air and causing it to fall back again on to the floor of the house.

It will be seen by reference to these figures (see diagram) that when the thermometer indicated 61° near the floor, the thermometer over the glass ceiling indicated 56°, while those around the sides were only 40° and 38°. I found a strong descending current of this cooled foul air descending on three sides, sweeping over the galleries, and tumbling down on to the floor.

This was bad enough through the day, when the air was only polluted by human beings, water closets, steam-engines, restaurants, etc.; but at night, when the products of many hundred gas-lights were added to it, it became almost insufferable. I noticed that in four minutes after the gas was turned on for lighting in the loft, we perceived it on the floor, and in fifteen minutes it became very oppressive.

I wish to call your attention particularly to this system of ventilating directly into a loft; I find it very often in churches, and in many other buildings where the openings are made directly into this space under the roof, and frequently in schools a whole system of flues will empty into such a place. Sometimes there will be a small blind window in the gables, and sometimes a small ventilator on the roof, but not connected with the ventilating flues.

This is all wrong—a very deceptive, pernicious system. If there